The Economic Impact of Technology-Based Industries in Washington State (2013)

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Executive Summary

Technology-based industries are a leading force in the development of the Washington economy. They account for the largest share of jobs, sales, and labor income of any major cluster of industries in the state's economic base. Natural resource dependent industries—including agriculture, fishing, food products, and forest products are also important to the state's economic base. Maritime industries, tourism and transportation, warehousing and wholesaling, and producer services not included in our definition of technology based industry continue as other significant elements in the state's economic base.

This study has defined technology-based industry on the basis of the occupational structure of the workforce, identifying industries with a relatively large share of their workforce in research and development (R&D) activities. This definition was developed by the U.S. Bureau of Labor Statistics to define "high tech" industries. In this study we have utilized data for the year 2013 from the Washington State Department of Employment Security (ESD) to define these industries. We have included (with a few exceptions) industries with at least twice the percentage of employment in computer related, engineering, and scientific occupations (16.6% or more); across all industries in the Washington economy 8.8% of employment was in these R&D related occupations. In 2013 technology-based industries had 41% of their workforce in these R&D related occupations, compared with just 3% employed in these occupations in other industries.

The most recent year of employment data from ESD for covered wage & salary employment, and from the Census Bureau for self-employed individuals was used in this study. The ESD data for the second half of 2012 and for the first half of 2013 were used, along with 2011 data from the U.S. Census Bureau for the self-employed, to estimate technology-based employment.

Technology-based industries have grown rapidly in Washington over the last several decades. Employment grew from 96,000 covered, private sector wage and salary jobs in 1974 to 408,286 jobs in 2013. Technology-based employment quadrupled, while employment in other industries doubled over this same time period. Covered employment in technology-based industries has grown from 6.7% to 14.1% of total state employment. In 2013, there were an additional 11,531 university and federal research related jobs in Washington State, and an estimated 40,425 self-employed people working in our technology-based industries, for a combined total of 460,242 technology-based jobs in 2013.

Through the use of the Washington State input-output model, we calculate a total of 1.38 million jobs were created in the Washington economy due to technology-based industries last year, which was 42% of total employment in the state. Similar percentages of overall impact were measured for sales, labor income, and selected taxes through use of the input-output model.

Economic impacts are related to purchases made by industries from other industries in the Washington economy and the level of labor income earned and spent as

consumption expenditures. Technology-based industries have a level of labor income ($120,005) that is more than double the average for other industries ($53,111), which results in a relatively high multiplier in the input-output model. The employment multiplier for technology based industries was 3 jobs per direct job, compared to 2.45 jobs per direct job for other industries. Technology-based industries also have a relatively high level of exports (70%) compared to other Washington industries (28%), thereby contributing strongly to the state's economic base.

Washington's employment in the industries covered by this study was 49% above the national average, driven by our high concentrations of employment in aerospace, software, and remediation and other waste management services. If the largest technology-based industry in Washington State (aerospace) is excluded, Washington still has a concentration of technology-based industry that is 33% above the national average. The concentration of aerospace employment is 7.9 times the national average, the concentration of software employment is 6.9 times the national average, and the concentration of remediation and other waste management services is 2.2 times the national average.

Research and development (R&D) expenditures in Washington State are an important indicator of the concentration of technology-based industry. The latest data on R&D expenditures from the National Science Foundation are for the year 2011. These data report that Washington ranked 6th nationally in total dollars used for R&D, while our state population is the 13th largest nationally, indicating a stronger concentration of R&D spending in Washington State than nationally. R&D spending in Washington in 2011 was 5% of our Gross State Product (GSP), compared to 2.8% nationally. Business R&D accounts for most R&D spending, and in this category Washington State ranks first in the nation when indexed against GSP. Overall, Washington ranks 4th nationally in R&D spending for all categories when indexed against GSP. Washington's position is also strong on funding for non-profit federally funded research and development centers and other non-profits; we rank 6th for both of these categories when they are indexed against GSP. In contrast, our position on university and college research is 24th when indexed against GSP, a reflection of our relatively small higher education system.

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I. Introduction

This report is the eighth estimate of the magnitude of employment, business activity, and income related to a major segment of the Washington State economy—our technology-based industries—commissioned by the Technology Alliance. A relatively high level of employment in research-related computing, scientific, and engineering occupations has been the basis for defining the industries included in these studies. While primarily in the private sector, some important segments of technology-based industries are public employers. Almost all segments generate a significant fraction of their business volume out-of-state, thereby contributing to the state's export base.

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 growth trajectory, and they will likely be an even more important component of the state economy in coming years. The latest industry employment projections from the Washington State Employment Security Department (ESD) project 20.4% growth in the technology-based industries included in this report between 2011 and 2021, compared to 15.0% for other industries in the state economy (these estimates exclude state and federal research activity and self-employment) (ESD 2013).

This report documents the growth and development of technology-based industries in the Washington economy up to the year 2013, as well as their impact on the aggregate state economy in the year 2013. Similar studies were released by the Technology Alliance in 1997, 1998, 2001, 2005, 2008, 2010 and 2012, benchmarked to 1995, 1997, 2000, 2003, 2007, 2009, and 2011 data, respectively (Beyers and Lindahl 1997; Beyers and Nelson 1998; Beyers and Lindahl 2001; Beyers, Andreoli and Hyde 2005; Beyers 2008; Beyers 2010; Beyers 2012).

Each of these reports started by defining the industries included in them. This is not an easy task, for terms such as "technology industry," "high technology," and "advanced technology" are frequently used by scholars, the media, political figures, and others to refer to 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 were 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 and other manufacturing industries to most employment being in service industries. This section

also presents information on the geographic distribution of technology-based industries among counties in Washington State, and on the size distribution of technology-based establishments in Washington State compared to the U.S. as a whole.

Section IV analyzes the impact of these industries on the Washington State economy. Direct, indirect, and induced employment; output (sales); labor income; and tax revenues generated by technology-based industries are presented, using the Washington State input-output model. These impacts are then compared to those of other industries. Approximately 42 % of total employment (covered and self-employed) in Washington State can be attributed to technology-based industries in the year 2013. Section V provides some concluding comments, including a brief overview of the history of the economic impact of technology-based industries in Washington State, as documented in previous Technology Alliance studies.

This report has six appendices. Appendix I contains a review of alternative definitions of technology-based industries used in recent studies in the United States. Appendix II provides technical notes about the input-output model used to calculate economic impacts. Appendix III contains detailed location quotients for technology-based industries in Washington State in 2011. Appendix IV documents the growth of detailed technology-based industries in Washington State from 1974 to 2002, as measured by the Standard Industrial Classification (SIC) definition of industries. Appendix V presents estimates of detailed employment levels in Washington State from 1998 through 2013, as measured by the North American Industry Classification System (NAICS). Appendix VI presents estimates of technology-based employment in Washington by county in 2013.

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

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

Each of these dimensions—the mix of industries, the method of production, and the intensity of use of the factors of production—have undergone revolutions in regions such as Washington State, as well as in national economies and globally. 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 Stewart 2012; Klowden and Wolfe 2013). There are numerous challenges involved in defining these industries. Factors considered in alternative definitions of technology-based industries include: the nature of the products or services they produce; characteristics of the production process; the structure of the labor force; the ratio of R&D spending as a fraction of sales revenues; and the length of product life-cycles.

Defining Technology-Based Industry

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

The definition of "high-tech" has been made more difficult in a world in which information technologies and other advanced technologies influence the way that business is done in every industry. Doctors and loggers use similar computer technologies as computer software makers and manufacturers of semiconductor chips to operate their businesses. So, there can be no question but that the nature of production has been altered by modern technologies across the economy, including the public sector.

The definition of technology-based industries in Washington State used occupational categories considered as R&D intensive by the U.S. Bureau of Labor Statistics (Hecker 2005). Table 1 lists examples of these occupational classifications. There were 96 occupations considered to be R&D related in the ESD's industry-x-occupation matrix used to define the industries included in this study. These are computer, engineering, and scientific occupations.

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 industries that have this commitment, and after considerable deliberation and evaluation of approaches taken in studies in other regions, a definition of at least 16.6% employment in R&D intensive occupations, or twice the state average for all industries, was established. With limited exceptions, the industries included in this study meet the 16.6% threshold.

Early Technology Alliance economic impact studies used a threshold of 10% employment in R&D occupations, a figure consistent with that suggested by the Bureau of Labor Statistics as an indicator of high-technology industry (Hecker 1999). The first

three studies examined industries defined by Standard Industrial Classification (SIC) categories. Since 2005 the Technology Alliance studies have used a spreadsheet obtained from ESD that provides estimates of employment by industry and occupation using the North American Industry Classification System (NAICS) to determine which studies meet the R&D employment threshold to qualify as technology-based.

Table 1 Selected Examples of R&D Intensive Occupations

Standard Occupational Category (SOC)	Occupational Description	% of Total
15-1131	Computer Programmers	5.1%
15-1132	Software Developers, Applications	16.2%
15-2031	Operations Research Analysts	0.8%
15-2041	Statisticians	0.5%
17-1011	Architects, Except Landscape and Naval	1.4%
17-2011	Aerospace Engineers	3.3%
17-2051	Civil Engineers	5.1%
17-2161	Nuclear Engineers	0.4%
17-3012	Electrical and Electronics Drafters	0.4%
17-3023	Electrical and Electronics Engineering Technicians	0.9%
19-1021	Biochemists and Biophysicists	0.1%
19-2041	Environmental Scientists and Specialists, Including Health	1.5%
19-3011	Economists	0.1%
19-4021	Biological Technicians	1.3%
	Other R&D Intensive Occupations	62.8%

Source: Washington State Employment Security Department, 2013 Occupational employment by industries for 2012Q2.xls

The data in these spreadsheets have reported significant increases in total employment in R&D intensive occupations, leading to the decision in recent studies to increase the percentage of employment in R&D intensive occupations used to define technology-based industries from 10% to twice the state average for all industries. It should be noted that the Bureau of Labor Statistics has also observed these same trends in occupational structure, and the role they play in developing their current definitions of technology-based industry (Hecker 2005).

An alternative to the Washington State industry-x-occupation matrix that could be used to define technology-based industries, as undertaken by the BLS, would be to use the U.S. industry-x-occupation matrix. This would yield a different set of industries than included in the current study, including some industries not present in the Washington economy. Since the purpose of this analysis was to report on Washington's technology-based industries, not the national set of technology-based industries, the Washington State industry-x-occupation matrix has been used as the basis for defining technology-based industry in this study. It is recognized that this decision alters the scope of the industries included in this research project, and also alters measures of Washington's comparative position to other states related to technology-based industry. Appendix I contains NSF's

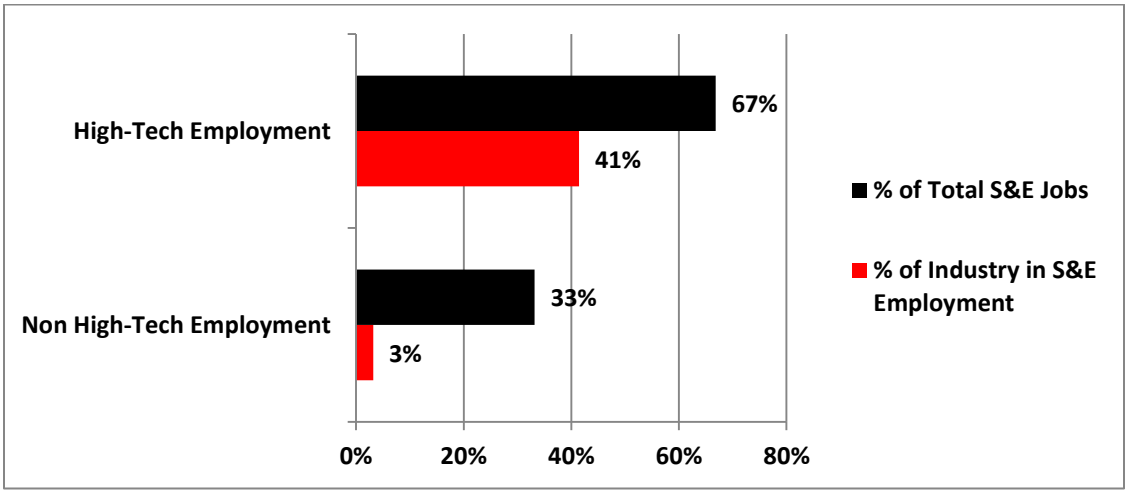
current definition of high-tech industry; this definition is similar to that used in this study, suggesting that these definitional issues may not be of enormous importance.

The ESD matrix of employment and occupations used in this study defines industries through the use of the 2007 NAICS codes; these codes are slightly different than the original set of NAICS codes first utilized by the federal government in 1997, and modified in 2002 and 2007. These redefinitions of the NAICS codes have presented difficulties in the consistent estimation of employment by industry over time as reported in Section III of this report. In a few cases the 2002 NAICS codes separated activities (such as Internet service providers) that were aggregated with broader categories in the 1997 NAICS, and then these categories were recombined with the 2007 NAICS redefinitions. However, the changes in the NAICS codes are a minor issue compared to the more general matter of drawing comparisons between the NAICS scheme and the SIC codes used in the earlier Technology Alliance studies, as discussed in Section III.

Shares of employment were calculated for each industry included in the 2012 industry-x-occupation matrix for computing, engineering, and scientific occupations (codes beginning with SOC 15, 17, and 19). These calculations found that 8.3% of total employment in Washington State was estimated to be in these occupations in the year 2012; hence, double this percentage (16.6%) was used as the primary basis for defining technology-based industry in the current study.

The industries that are included in this study after this process of evaluation are listed in Table 2, along with the corresponding percentage of R&D employment. Figure 1 indicates that the majority (67%) of computer, engineering, and science workers are employed in technology-based industries. However, 33% are employed in other industries, the majority in computer-related occupations. Technology-based industries have an average of 41% of their workforce in computer, science, and engineering occupations, compared to 3% in other industries in the Washington economy.

Figure 1 Computer, Engineering, and Science Jobs in Technology-Based and Other Industries in Washington State, 2012



Three industries included in Table 2 have less than 16.6% R&D-related employment: metalworking machinery, chemicals, and commercial equipment merchant wholesalers. These sectors were included after careful examination of their occupational structure. Metalworking machinery has a relatively high share of employment in engineering occupations, but modest levels of computer-related occupations, and no employment in scientific occupations. Chemicals manufacturing has a strong concentration of scientific occupations, but modest concentrations in computer science and engineering occupations. Commercial equipment merchant wholesalers have a very strong concentration of employment in computer related occupations, but a small percentage of employment in scientific and engineering occupations.

Table 2 R&D Employment Concentration in Washington's Technology-Based Industries

NAICS	Industrial Definition	% R&D
	Technology Intensive: R&D Occupations over 30%	
5413	Architectural & Engineering Services	68.5%
5415	Computer Systems Design & Related Services	62.9%
5112	Software Publishers	62.2%
5417	Scientific Research & Development Services	58.0%
519	Other Information Services	43.6%
518	Data Processing & Related Services	38.2%
4541	Electronic Shopping & Mail-order Houses	37.2%
3364	Aerospace	35.7%
	University and Federal Research	(Not covered in ESD data base; see text)
	Other Technology Industries: R&D Occupations 14.7% to 30%	
5615	Travel Arrangement & Reservation Services	28.1%
334	Computer & Electronic Products Manufacturing	27.4%
5416	Management, Scientific, & Technical Consulting Services	27.2%
517	Telecommunications	24.6%
5629	Remediation & Other Waste Management Services	24.2%
3336	Turbine & Power Transmission Equipment Manufacturing	22.1%
55	Management of Companies & Enterprises	20.4%
3363	Motor Vehicle Parts Manufacturing	19.5%
324	Petroleum & Coal Products	17.5%
3335	Metalworking Machinery Manufacturing	15.9%
325	Chemicals Manufacturing	15.0%
4234	Commercial Equipment Merchant Wholesalers	14.7%
	All Technology-Based Industries	**41.4%**

Two industrial classifications included in the ESD employment-x-occupation matrix had a high concentration of employees in research-related occupations, but were excluded from this study. They were the federal government and "state government other," with 21.0% and 16.2% employment in research-related occupations, respectively. These two industrial classifications had a large level of employment (61,337 federal and 59,168 state government other). However, we could not determine what categories of government activity were included in these two industrial classifications, and we have included some activity in government in this study. In future studies of this type, it would be useful if the ESD could categorize the agency structure of these two sectors, to isolate where these research-related employees are concentrated.

University and Federal Research

Two categories included in Table 2, 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 research-related workers at the University of Washington and Washington State University (UW 2013; Downes 2014). The federal research organizations include National Oceanic and Atmospheric Administration (NOAA) agencies in Washington State and the Naval Undersea Warfare Center Division Keyport (NUWC Keyport Division 2014; ESD 2013b). 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 this study.

Life Sciences

Life sciences (including biotechnology and medical devices) are not identified separately in the NAICS codes shown in Table 2. Most biotechnology and medical device 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 devices is included in pump and compressor manufacturing (NAICS 3391), an industry that did not meet the criteria for inclusion in this study.

The Washington Research Council estimated that 10,038 people were employed in biotechnology and medical devices in Washington State in 2010[1]. Its report documented 2,085 people employed in drug and pharmaceuticals manufacture (NAICS 3254), and 7,953 employed in medical devices and equipment (NAICS 3345 and 3391). The council estimated 3,730 people were employed in biotech research, which is about 19% of total employment in scientific research and development services (including self-employed) in this current Technology Alliance study.

[1] This figure is based on the Washington Research Council's Washington Life Sciences Economic Impact Study, released in November 2011, which was the most recent data available to this author at the time this report was prepared.

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

The industries defined in Table 2 with high proportions of their labor force in research-intensive occupations are also likely to devote relatively high proportions of their expenditures on R&D activities. Data from the National Science Foundation (NSF) are reported annually on a wide range of indicators of scientific and engineering effort at the national and state level. Before turning to an historical and comparative account of the importance of employment in technology-based industries in Washington, the state's position with regard to these measures is reviewed.

Table 3 details Washington's position on a variety of measures of R&D funds using NSF data. The latest data are for the year 2011, while the primary benchmark for this study is 2013. Two rank measures are provided: (1) total dollars spent, and (2) ranks based on indexed estimates of spending relative to Gross State Product (GSP). Washington's overall position is 6th nationally based on total spending and 4th nationally when viewed from an indexed perspective.

Table 3 Washington State Distribution of R&D Funds, 2011

Performer and Sources of Funds	$ Millions	2011 Rank $ Used	2011 Rank Indexed	2008 Rank $ Used	2000 Rank $ Used	1993 Rank $ Used
United States Sources: Total Used	$17,979	6	4	6	8	11
A. Federal Government: Total Used (1)	$268	19	18	24	14	21
B. Business: Total Used (2)	$14,558	4	1	3	7	9
Federal Sources	$578	12	16	13	D	8
Business Sources (3)	$13,980	4	1	2	D	10
C. Universities & Colleges: Total Used(4)	$1,570	13	24	34	14	14
Federal Sources	$1,091	13	16	25	11	10
Non-federal Government Sources	$92	11	20	32	35	32
University & College Sources	$234	19	38	40	22	NA
Business Sources	$35	21	40	11	11	14
Non-Profit Sources	$119	11	13	38	27	NA
D. Non-Profits: Total Used (5)	$1,504	6	5	4	4	5
Non-profit FFRDC	$1,137	7	6	4	4	NA
Other Non-profits	$367	3	6	6	7	NA
E. State Internal (6)	$10	11	22	NA	NA	NA

Notes:

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

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

(3) Business R&D support to business performers includes all non-federal 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 (FFRDCs), such as the Battelle Memorial Institute. Estimated non-federal support to the non-profit sector is excluded from these state data.

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

NA – Data not available for this year; NSF measures these data biennially. D – data not disclosed

Source: National Science Foundation 2014

Washington's comparative position has improved since the last Technology Alliance economic impact study, which used data for 2008. NSF data show on a variety of key indicators that Washington is in a strong position with regard to R&D activities. In 2011, NSF estimated Washington-based entities used $18 billion in R&D funds, which was 5.04% of our GSP; nationally, R&D was 2.84% of Gross Domestic Product (GDP). This placed us 6th among the states based on total spending, well above our position as the 13th most populous state in the country (Census 2013). This relative concentration of expenditures on R&D activities is mirrored in the next section of this report, which demonstrates that Washington's employment concentration in technology-based industries, as defined in this report, is also well above the national average. In 2010 the concentration of doctoral scientists and engineers employed in Washington State also exceeded the national average[2].

Business dominated Washington R&D expenditures in 2011, as it did nationally (70% of national R&D was performed by business; in Washington State, 81% of R&D funds were used by business). Washington ranks 4th nationally in business R&D dollars expended, and 1st when indexed to GSP. In Washington, business 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, and by the Microsoft Corporation[3]. Federal R&D activity in Washington is largely at the Naval Undersea Warfare Center Division Keyport and at NOAA.

University and college funds accrue primarily to the University of Washington and Washington State University. University and college research spending yielded a ranking (13th) that is the same as our population rank. However, when indexed to GSP, Washington's position falls to 24th, largely due to relatively weak non-federal government (e.g. state government), business, and university and college funding sources (such as endowments). While Washington ranks 13th nationally in the receipt of federal university and college research funds, our position falls to 16th once expenditures 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 (Osborne & Beyers 2013).

Notable in Table 3 is the receipt of funds by non-profits, as defined by NSF, which in Washington State is dominated by funding to the Fred Hutchinson Cancer Research Center in the other non-profits sector, and by the Battelle Memorial Institute (Pacific Northwest National Laboratory) in the non-profit FFRDC sector. Washington's ranking as the 7th highest recipient of research funds by non-profit FFRDC's and the 3rd highest recipient of research funds by the other non-profit sector highlights the importance of these organizations to the state's R&D activities.

[2] This conclusion is based location quotients calculated from data in NSF Science and Engineering Profiles by State (last updated February 2014, for employed S&E doctorate holders by state for the year 2010 and employed workforce by state),Table 8-35.
[3] Unfortunately, NSF does not disaggregate business R&D activity by industry due to disclosure laws.

Although it is not possible to classify expenditures of R&D funds by NAICS code, it is certain that almost all of these funds were received by industries covered in this study. Again, the impacts considered in this analysis are based on all of the business activity in the industries which have high levels of R&D employment, not only the impact of activities directly associated with R&D expenditure.[4] It should be noted that Washington's position on a number of the indicators reported in Table 3 has improved, as our ranking has moved up for most measures from the spending ranks calculated in the early Technology Alliance economic impact studies.

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

Current Employment

In 2013, technology-based industries employed 460,242 people in Washington State, 13.9% of the state's total covered employment and non-employer base of 3.315 million. As Table 4 reports, and Figure 2 illustrates, manufacturing industries accounted for 28% of total technology-based jobs, with aerospace and motor vehicle manufacturing being the largest single category (21% of the total). The remaining 31,685 manufacturing jobs are divided between machinery and computer and electronics manufacturing (22,861 jobs), and petroleum refining and chemicals (8,824 jobs).

Covered employment is the average of data from the Washington State Employment Security Department for the 2nd half of the year 2012, and the first half of the year 2013 (ESD 2013b, ESD 2014). The non-employer data is from the U.S. Census Bureau, benchmarked against the year 2011, the latest year for which data were available.

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

Table 4 Employment in Technology-Based Industries, 2013

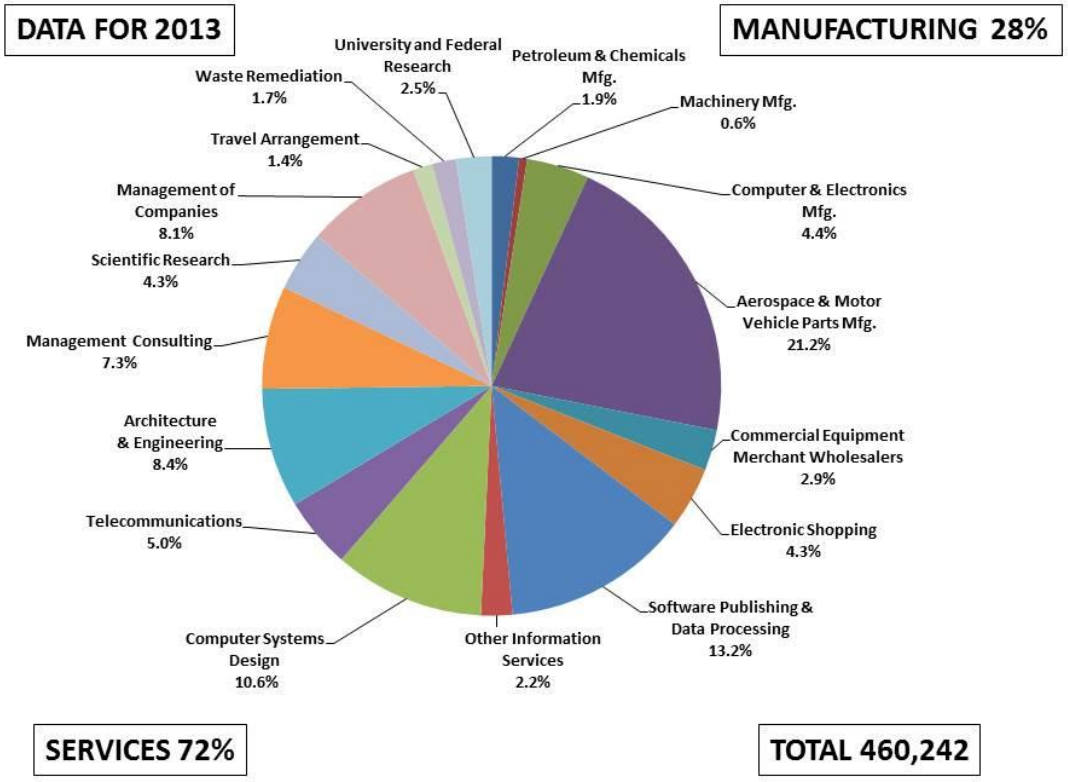
Industries	Covered Employment	Non-employer	Total
Petroleum & Chemicals Manufacturing	8,603	221	8,824
Machinery Manufacturing	2,564	53	2,617
Computer & Electronic Products Manufacturing	19,984	260	20,244
Aerospace & Motor Vehicle Parts Manufacturing	97,485	159	97,643
Commercial Equipment Merchant Wholesalers	12,994	209	13,203
Electronic Shopping & Mail Order Houses	16,964	2,969	19,933
Software Publishing & Data Processing	58,378	2,586	60,964
Other Information Services	8,634	1,493	10,127
Telecommunications	22,542	525	23,067
Architecture & Engineering	33,197	5,575	38,772
Computer Systems Design	40,086	8,756	48,842
Management, Scientific & Technical Consulting	17,349	16,054	33,403
Scientific Research & Development	18,865	813	19,678
Management of Companies & Enterprises	37,362	0	37,362
Travel Arrangement & Reservation Services	5,673	624	6,297
Remediation & Other Waste Management Services	7,607	128	7,735
University & Federal Research	11,531	0	11,531
Total	**419,817**	**40,425**	**460,242**

Sources: Washington State Employment Security Department, U.S. Census Bureau

The bulk of technology-based employment in Washington State is found in a variety of non-manufacturing industries. This category includes sectors that provide services—for example, architecture and engineering—and industries that produce intellectual property-based goods, software being a prominent example. The information sector (composed of software publishers, data processing, telecommunications, other information services, and computer systems design) accounts for 31% of total technology-based employment. Producer services include architecture and engineering, scientific research and development, management and technical consulting, management of companies and enterprises, and remediation and other waste management services. Together, these industries account for 30% of total technology-based employment.

The balance of technology-based jobs are found in commercial equipment merchant wholesaling, electronic shopping and mail-order houses, travel arrangement, and university and federal research activities. These industries account for 11% of total technology-based employment.

Figure 2 Breakdown of Employment in Technology-Based Industries, by Percentage of Total Technology-Based Employment



Employment Trends

In the first four Technology Alliance economic impact studies, we were able to construct detailed information on employment by broad lines of technology-based industry (excluding university and federal research) back to 1974. This time series was based on the SIC classification system.

With the shift to the NAICS classification system there are two important changes that make it impossible to present a harmonious estimate of employment trends from 1974 to 2013. 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 computing, engineering, and scientific occupations. Management of companies and enterprises is a good example of this second issue.

There is a third issue that arises in making such comparisons: the changing occupational employment mix in particular industries. Whereas some industries were

excluded from earlier definitions of technology-based industry, the evolution of their occupational mix has led to their inclusion under the current definition. Petroleum refining is an example of this—it did not qualify for inclusion in the 2008 study, but it is included in the current study. Even under the SIC system there were discontinuities in classification, such as the movement of much of Hanford from chemicals (plutonium) manufacturing to services in 1991.

There are no perfect solutions to these statistical issues. The easiest solution is to include in this section both the historical data in the SIC format, to provide information on the evolution of technology-based industries (Table 5), as well as the data in the NAICS format (Table 6). Table 6 presents data for the years in which NAICS data are available, and while the totals do not add up perfectly to the values in Table 5, they allow us to have some evidence regarding the recent evolution of technology-based employment in the industries included in the current study under these two systems of measurement in the years when the government reported statistics in both formats (1997-2002).

Figure 3 presents estimates of private sector covered employment in technology-based industries from 1974 through 2013. This figure shows estimated aerospace employment; software and computer services employment (including data processing, computer systems design, and other information services); and other technology-based employment. The figure illustrates the significant growth of non-aerospace technology-based employment in Washington. It uses the SIC industry definitions up to 2002, and uses the NAICS definitions for the years after 2002. Figure 3 excludes university and federal research and self-employment data, as historical data on these activities are not available. Figure 3 reports over the course of the NAICS history employment levels based on the definition of technology-based industry used in the Technology Alliance economic impact study that year. In contrast, the data in Table 6 reports historic NAICS data for the current study's definition of technology-based industry.

The three broad groups of industries displayed in Figure 3 have significant differences in research-related occupational structure in the three SOC's used to define technology-based industries included in this report (ESD 2013a). The aerospace sector has 68% of its research-related employment in engineering occupations, 31% in computer-related occupations, and 1% in scientific occupations. In contrast, software and computer services industries have 99% of their research-related employment in computer science occupations, 1% in engineering occupations, and no scientific occupational employment. The "other technology-based industries" category has a more diversified pattern of research-related employment: 36% in computer science occupations, 43% in engineering occupations, and 21% in scientific occupations. Five industries within this "other" category have research-related employment in which computer science occupations dominate: electronic shopping and mail order houses; travel arrangement and reservation services; telecommunications; management of companies and enterprises; and commercial equipment merchant wholesalers.

Employment Trends 1974-2002

The growth of private sector employment in Washington's technology-based industries defined on an SIC basis was steady in the aggregate, increasing from 95,910 in 1974 to 259,648 in 2002, or 171%, as described numerically in Table 5 and in more detail in Appendix IV. This compares to total wage and salary employment growth of 92% in the Washington economy during the same period. 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 more than twelve-fold between 1974 and 2002. Software and computer services also expanded twelve-fold over the same period. Aerospace, while the largest single tech-based industry employer became 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 2002 its share had fallen to 23%.

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

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

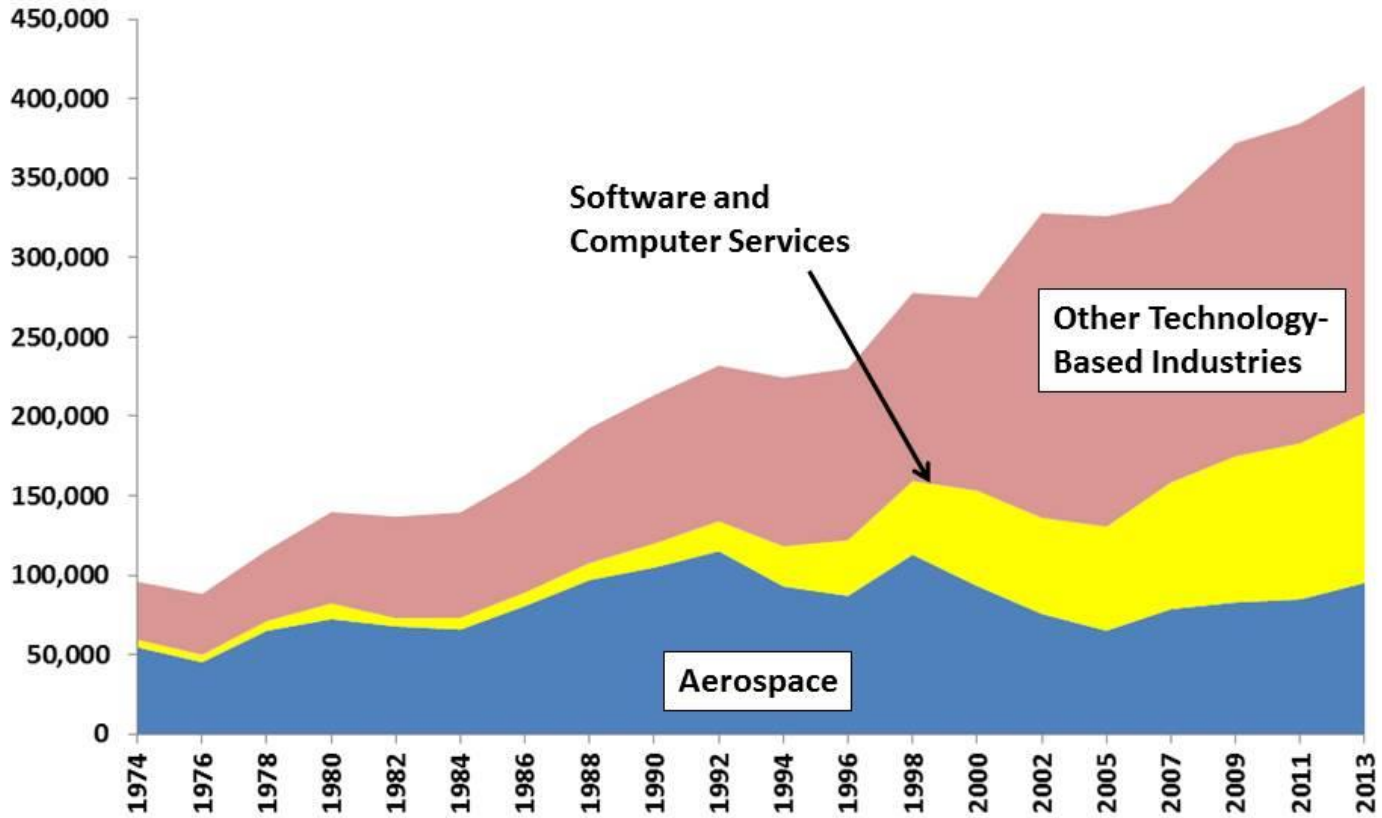
Table 5 Employment History for Washington State Technology-Based Industries, 1974-2002 (private-sector covered employment; SIC-based definitions)

	% Chg. 74-02	2002	2000	1998	1996	1994	1992	1990	1988	1986	1984	1982	1980	1978	1976	1974
Manufacturing																
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 Products	**-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	**1,266%**	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
Services																
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	**1,239%**	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, 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, 1974-2013 (covered employment, excluding government and university research activities)



Sources: U.S. Census Bureau County Business Patterns, Washington State Employment Security Department

A Note on Hanford

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

With the end of plutonium manufacture and the shift of the federal effort at Hanford towards environmental cleanup, the classification of the employees who were considered part of the inorganic industrial chemicals manufacturing industry were shifted to research and testing (SIC 873). This change of classification was undertaken by ESD in 1991. In our historical employment series for SIC 281 and 873, the impact of this change of classification is evident. In the ongoing cleanup efforts at Hanford in recent years, most employment has been reclassified again, and is now in waste remediation (NAICS 5629), an industry included in the current study, with an estimated 4,131 people employed in this industry in Benton County in 2013. Federal Department of Energy employment at Hanford is not included in this study, but it is probably in the range of 500 employees. The Employment Security Department reports a total of 753 federal employees in Benton County in 2013, and a total of 529 persons in the administration of air, water, and waste programs in Washington State (NAICS 924110) in 2013 (ESD 2014).

Employment Trends Since 1998

Table 6 presents estimates of employment for the 1998-2013 time period by NAICS definitions used in this study. More detail on the history of employment by NAICS codes is found in Appendix V. NAICS codes were changed in 2002 and 2007, rendering some sectors non-comparable (NC) due to these definitional changes. This table documents the rapid growth of employment in software publishing and computer systems design, scientific research and development, and electronic shopping and mail order houses. The aerospace employment cycle is evident in this table as well, with a large drop in employment between 1998 and 2005, and a rebound after 2005. The employment history in various 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 was recorded in computer manufacturing. These changes may be related to reclassifications of establishments as a result of changes in NAICS classification principles. Changes in NAICS codes in 2002 and 2007 have affected the definitions of industries included in the various Technology Alliance economic impact studies, leading to some discontinuities in employment statistics in cases where these redefinitions have made it impossible to classify industries in a harmonized manner.

Table 6 Employment Trends for NAICS Technology-Based Industries (excluding university and federal research employment)

NAICS		% Change 1998-2013	2013	2011	2009	2007	2005	2002	2000	1998
	Manufacturing									
324	Petroleum & Coal Products Manufacturing	20.9%	2,463	2,370	2,606	2,444	2,314	2,726	2,030	2,037
325	Chemicals Manufacturing	15.4%	6,140	5,824	5,796	5,919	5,202	5,798	4,842	5,320
3335, 3336	Machinery Manufacturing	33.9%	2,564	2,094	2,232	2,410	2,169	1,397	1,990	1,915
334	Computer & Electronic Products Manufacturing	-58.1%	19,984	19,477	21,539	22,576	22,003	25,948	45,554	47,720
3363	Motor Vehicle Parts Manufacturing	-18.5%	2,299	1,749	1,736	2,334	2,812	2,688	3,024	2,821
3364	Aerospace Manufacturing	-15.7%	95,186	84,831	82,932	78,667	65,096	75,667	93,221	112,962
	Services									
4234	Commercial Equipment Merchant Wholesalers	NC	12,994	13,397	14,195	14,277	13,774	14,399	NC	NC
4541	Electronic Shopping and Mail Order Houses	258.3%	16,964	11,154	8,906	10,833	9,614	9,586	6,613	4,734
5112. 518, 5415	Software Publishers, Data Processing, and Computer Systems Design	230.4%	98,464	91,286	87,425	79,643	65,445	60,488	54,486	29,803
517	Telecommunications	-25.4%	22,542	24,389	25,741	26,140	25,717	30,988	32,975	30,200
519	Other Information Services	NC	8,634	6,994	4,515	NC	NC	NC	NC	NC
5413, 5416, 55	Architectural & Engineering Services; Management, Scientific & Technical Consulting Services; Management of Companies & Enterprises	-3.7%	87,908	82,079	82,273	80,282	74,183	68,126	88,347	91,273
5417	Scientific R&D Services	98.8%	18,865	20,027	19,117	18,765	18,090	16,354	10,936	9,489
5615	Travel Arrangement & Reservation Services	-32.5%	5,673	7,120	8,243	6,396	6,237	6,633	8,531	8,399
5629	Remediation & Other Waste Management Services	42.2%	7,607	9,590	8,665	8,319	7,918	7,640	6,594	5,350
	Total	NC	408,285	382,381	375,921	378,133	339,249	NC	NC	NC
	Estimate for 1998 through 2002						At Least	346,907	359,143	352,023

Sources: Washington State Employment Security Department, U.S. Census Bureau County Business Patterns
NC=not comparable

Concentration of Technology-Based Industries in Washington State

Washington State's concentration of technology-based employment, as defined in this series of studies, 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 and the dot-com bust, the concentration of technology based employment declined somewhat in Washington. In 2011, the latest year for which national data by state were available, Washington's concentration of technology-based industries was 49% above the national average.

Table 7 identifies "location quotients" for each of the NAICS technology-based sectors. The location quotient is a simple measure of the relative concentration of a particular industry in a region compared to the concentration of that industry for a benchmark region; in this study nation as a whole is the benchmark region. A value less than 1.0 indicates that an industry is underrepresented in a state or region, a value over 1.0 indicates a higher level of concentration than the nation, and a value around 1.0 indicates that the concentration of an industry within the state or region is similar to that within the national economy[5]. Table 7 uses two measures of employment: U.S. County Business Patterns, and the U.S. Census Bureau Nonemployer Statistics. The nonemployer data are derived from tax returns filed with the Internal Revenue Service by self-employed persons, in which they self-identify the industry from which they are receiving self-employment income.

The 2011 data for technology-based self-employment in Washington State indicate that their number was 9.8% of the total number of people reported as self-employed in County Business Patterns; this compares to 18.1% economy-wide. Thus, technology-based industries have a lower share of self-employed workers than in the economy as a whole. The number of self-employed persons in the United States has gradually increased in recent years; their inclusion in the statistical basis for calculating location quotients does not change significantly Washington's overall concentration, but it does provide a broader basis for calculating these indices. The Washington input-output models used for economic impacts includes self-employment in measures of labor income and employment.

[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 were compared to other states in the United States.

Table 7 Location Quotients in Washington's Private Sector Technology-Based Industries, 2011

NAICS Codes	Industries	CBP	Non-employer	Combined
324	Petroleum & Coal Products Manufacturing	0.685	0.487	0.694
325	Chemicals Manufacturing	0.381	0.902	0.396
3335, 3334	Machinery Manufacturing	0.418	0.799	0.431
334	Computer & Electronic Products Manufacturing	0.978	1.478	1.002
3361, 3363	Aerospace & Motor Vehicle Parts Manufacturing	3.735	1.568	3.796
4234	Commercial Equipment Merchant Wholesalers	1.131	1.053	1.151
4541	Electronic Shopping & Mail Order Houses	1.109	1.600	1.204
5112, 5415	Software Publishers & Computer Systems Design	2.276	1.710	2.198
517	Telecommunications	1.097	0.917	1.111
518, 519	Data Processing & Other Information Services	1.558	1.183	1.507
5413, 5416, 55	Business Services	1.331	1.343	1.336
5417	Scientific R&D	1.204	1.355	1.228
5615	Travel Arrangement & Reservation Services	1.490	0.884	1.416
5629	Remediation & Other Waste Management Services	2.277	0.963	2.244
	All Technology-Based Industry	**1.488**	**1.399**	**1.491**

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

The strongest concentration of technology-based industry in Washington State is in aerospace and motor vehicle parts manufacturing, with a location quotient of 3.80. No other sector included in this study approaches this dominance. Software publishers & computer systems design, as well as remediation and other waste management services, have a concentration 2.2 times the national average. Commercial equipment merchant wholesalers, telecommunications, data processing and other information services, business services[6], and scientific R&D are all above the national average in concentration. Appendix III presents location quotients for more detailed industries than those contained in Table 7, and these data make it clear that Washington's strongest industrial concentration is due to aerospace, in which our location quotient is 7.9, while in motor vehicle parts manufacturing our location quotient is only 0.2.

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

The location quotient for all technology-based employment, based on the mix of industries covered by this report, placed Washington 1st, with a location quotient of 1.49,

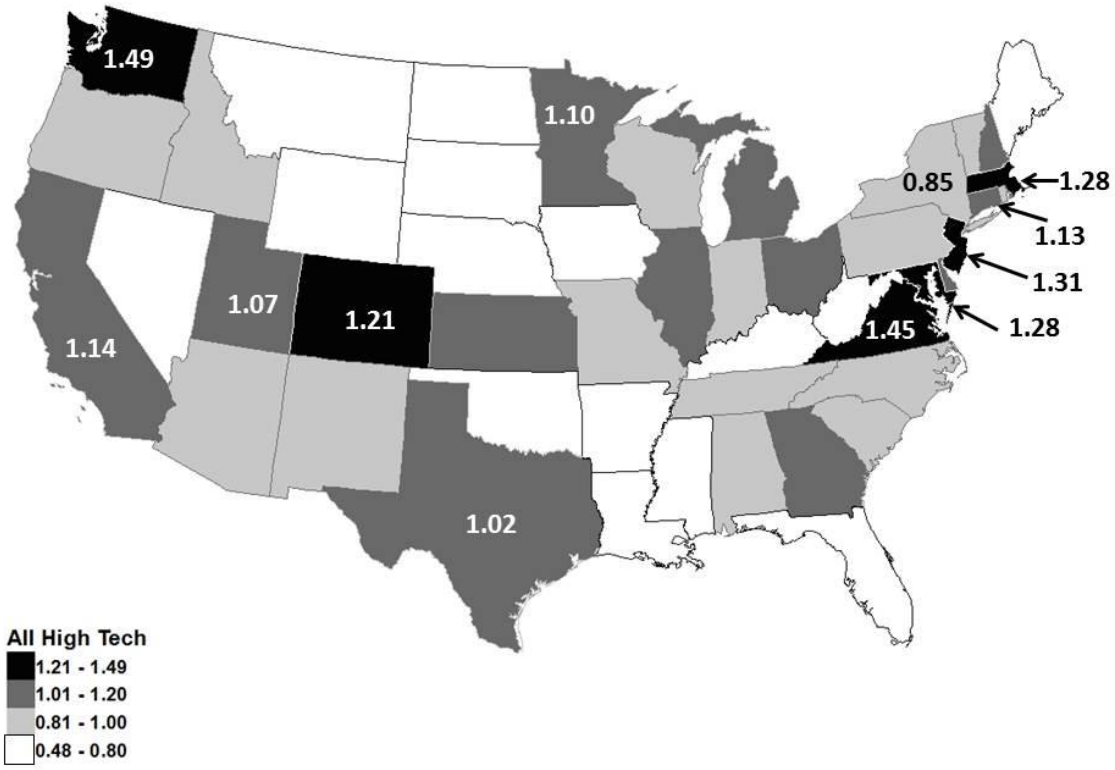
[6] Including Management of Companies & Enterprises, Architectural & Engineering Services, and Management, Scientific & Technical Consulting Services.

followed by Virginia at 1.45. Virginia has strong concentrations in data processing; architectural and engineering services; computer systems design; management, scientific and technical consulting; and scientific research and development.

New Jersey has strong concentrations in chemicals manufacturing; commercial equipment merchant wholesalers; computer systems design; management of companies; remediation and other waste management services; management, scientific and technical consulting; and scientific research and development. Massachusetts is heavily concentrated in computer and electronics manufacturing, software, and scientific research and development. California has multiple concentrations of technology-based industries, including machinery manufacturing, software, commercial equipment merchant wholesalers, telecommunications, architecture and engineering, and computer systems design.

Maryland has high concentrations in architecture and engineering; computer systems design; scientific research and development services; and management, scientific, and technical consulting services.

Figure 4 Location Quotients for Technology-Based Employment in the U.S. (industries defined as in Table 2, excluding university and federal research)

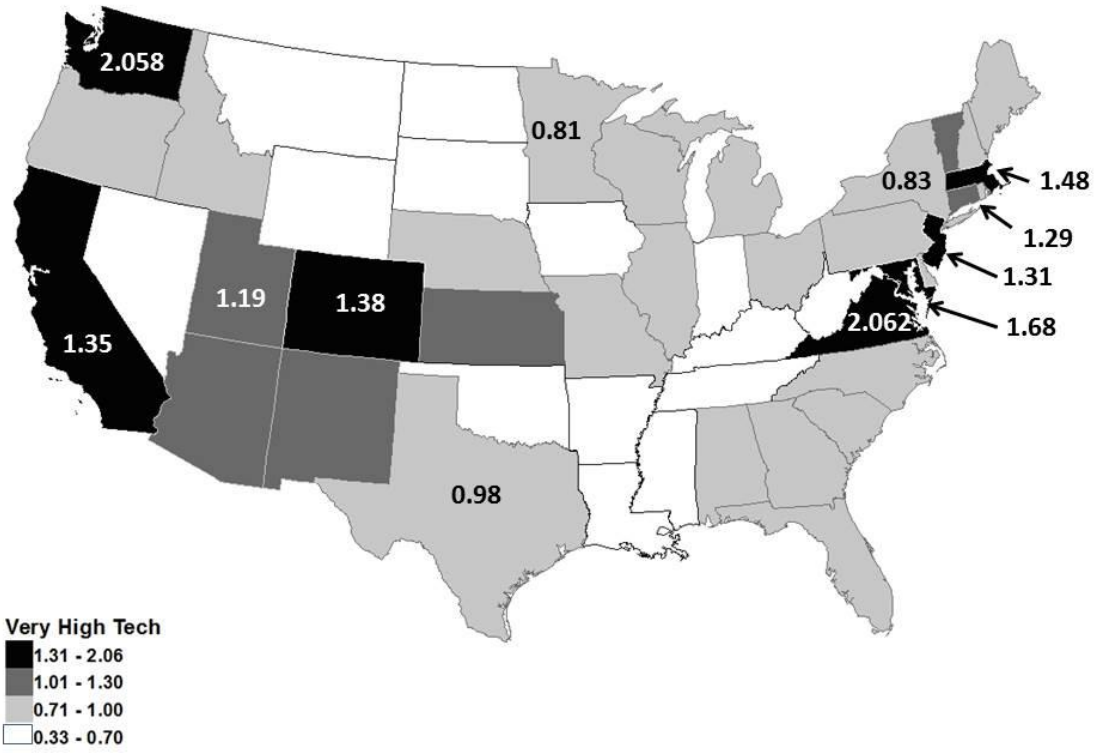


In the 1997 Technology Alliance economic impact study, Washington ranked 6th in the U.S. in its location quotient for technology-based industries, as they were defined in that report, using data for the year 1993. In the 1998 study, we were propelled to the top of the nation in our concentration of these industries, a ranking based on data for 1995. Washington retained this position in the 2001 study, using national data for 1997. In the 2005 study, our position slipped to 3rd and then, in the 2008 study we ranked 4th, fueled primarily by employment losses in the aerospace sector. In the 2010 study Washington also ranked 4th nationally. Using the current definition of technology-based industries, Washington ranked 1st nationally, moved upward by growth in a broad spectrum of technology-based industries in Washington State.

It is not possible to tease apart precisely the relative contributions to Washington's shifting position in these location quotients in industry detail due to the shift from the SIC to the NAICS classification schemes, and changes in the definition of technology-based industry in these studies. However, with the growing importance of services in the definition of technology-based industry, it is clear that states such as Virginia, Maryland, Connecticut, and New Jersey are strong competitors with their proximity to the nation's capital and our leading financial center, New York City. Washington's position is strongly impacted by our very strong concentration in software publishing—our location quotient is 6.9, more than double that of the closest other state (Massachusetts, with a value of 2.7).

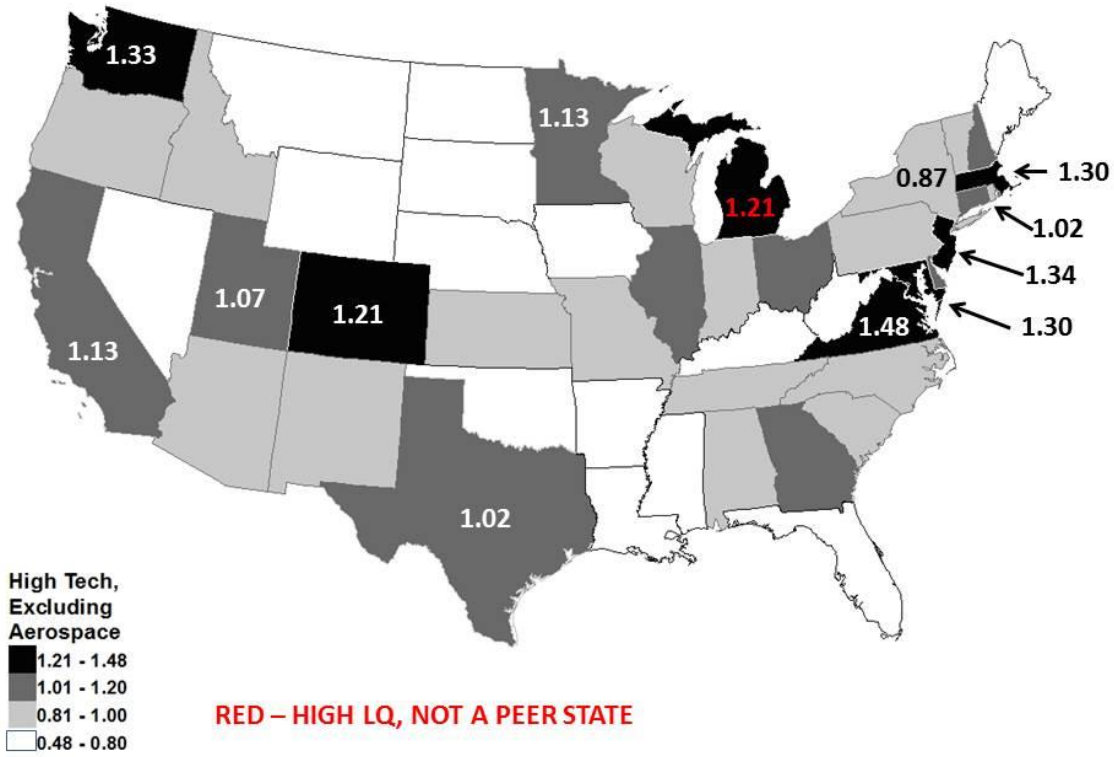
Figure 5 identifies patterns of industries that are "technology-intensive," or those with greater than 30% of employment in R&D occupations (see Table 3 for a list of these industries). The inclusion of aerospace and software publishers in this category (26% of employment in R&D occupations within Washington State are in these two sectors), is responsible for our very high concentration (2.058)—the second highest index in the nation after Virginia (2.062). It should be noted that Washington and Virginia have much higher concentrations of these "technology-intensive" industries than other states, as reported in Figure 5.

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



The strong contribution of aerospace to the high location quotients for Washington State depicted in Figures 4 and 5 is more sharply evident when the sector is excluded from the calculation, as shown in Figure 6. Without aerospace Washington's technology-based industry location quotient falls to 1.33. Washington State enjoys an unsurpassed dominance in its concentration of aerospace employment (a location quotient of 7.9). The other state with a very high concentration of aerospace employment is Kansas (with a location quotient of 7.6), but this state is currently not a national center of non-aerospace technology-based manufacturing, so its location quotient on Figure 6 is relatively low. The industries that pull us up to the national average are computers and electronics, software, research, and waste remediation. States that have the highest location quotients in Figure 6 (Virginia and New Jersey) have strong concentrations in a variety of technology-based services, but not in software.

Figure 6 Location Quotients for Non-Aerospace Technology-Based Employment



Size Distribution of Technology-Based Establishments

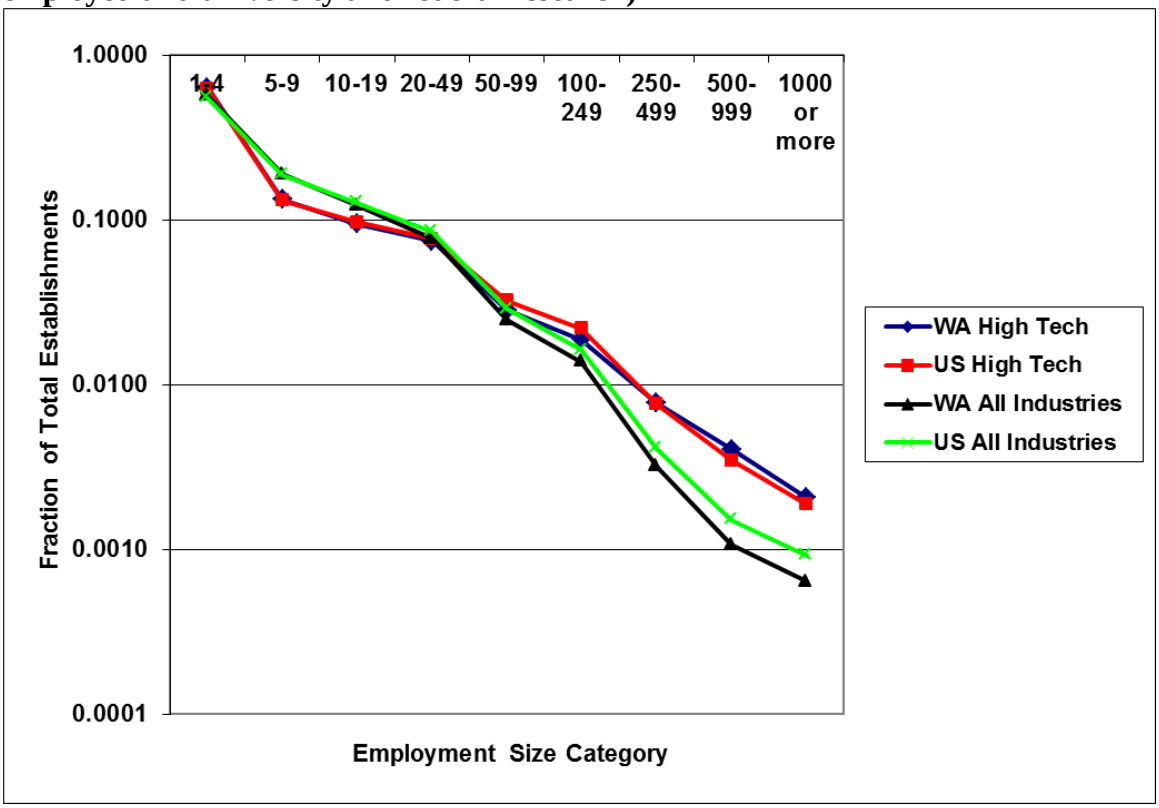
County Business Patterns (CBP) provides establishment counts by size category, while the Nonemployer Series provides estimates of proprietorships. These data are presented in Table 8, and in Figures 7, 8 and 9. These data indicate that 15,975 technology-based establishments in Washington State employed a total of 414,136 people in 2011, with an average of 26 employees per establishment[7]. The Nonemployer Series for 2011 contains an additional 40,425 individuals, most of whom are reported in services, with 40% of the total reported in NAICS 5416, management, scientific, and technical consulting.

Figure 7 is presented in a semi-logarithmic format, and includes the size distribution of technology-based establishments in Washington State and the United States, as well as the distribution for employment in all industries. This figure clearly indicates (1) a similar size distribution for technology-based establishments in Washington State and in the United States, and (2) the fact that Washington and U.S. technology-based industries have a "tail" of larger establishments (over 100 employees). Figure 8 shows the estimated total employment by size category, using the estimated size

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

per establishment reported in Table 8[8]. Figure 8 reports that almost half of employment in Washington technology-based industries are in establishments with 500 or more employees. In contrast, Figure 9 indicates the very skewed distribution of establishment size, with 99.4% of the total establishments employing fewer than 500 people, and 86.4% employing fewer than 20 people.

Figure 7 Size Distribution of Technology-Based Establishments, 2011 (excludes self-employed and university and federal research)



[8] 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 8 Size Distribution of Technology-Based Establishments in Washington State

NAICS		Total Establishments	1-4	5-9	10-19	20-49	50-99	100-249	250-499	500-999	1,000 or more	Non-employer
324	Petroleum & Coal	26	7	3	3	5	1	3	3	1	0	17
325	Chemicals	231	88	39	41	39	11	11	0	2	0	204
3335	Metalworking Machinery	59	27	9	7	11	0	3	2	0	0	46
3336	Turbine & Power Transmission Manufacturing	13	5	3	1	2	1	1	0	0	0	7
334	Computer & Electronic Products Manufacturing	324	131	46	36	54	23	20	3	8	3	260
3363	Motor Vehicle Parts Manufacturing	74	35	12	9	8	6	3	1	0	0	4
3364	Aerospace Manufacturing	109	26	12	19	11	10	16	7	3	5	155
4234	Commercial Equipment Merchant Wholesalers	812	435	138	114	71	28	17	5	3	1	209
4541	Electronic Shopping & Mail-order Houses	722	505	102	50	31	17	14	3	0	0	2,969
5112	Software Publishers	334	128	54	55	44	21	13	8	4	7	1,758
517	Telecommunications	1,095	592	158	162	100	38	20	15	8	2	525
518	ISPs & Data Processing	336	136	63	47	49	19	12	3	6	1	828
519	Other Information Services	290	179	36	23	23	10	11	8	0	0	1,493
5413	Architectural & Engineering Services	2,946	1,840	457	306	225	70	37	10	0	1	5,575
5415	Computer Systems Design	3,008	2,175	354	215	157	55	32	13	6	1	8,756
5416	Management, Scientific & Technical Consulting	3,425	2,872	248	148	101	32	17	5	1	1	16,054
5417	Scientific R&D	456	218	74	63	57	20	14	6	2	2	813
55	Management of Companies & Enterprises	978	338	163	140	162	72	49	29	19	6	0
5615	Travel Arrangement & Reservation Services	491	321	102	33	15	11	4	3	0	2	624
5629	Remediation & Other Waste Management Services	246	126	50	35	22	7	3	0	2	1	128
	All Technology-Based	15,975	10,184	2,123	1,507	1,187	452	300	124	65	33	40,425
	Average Employment	25.92	2	7	13	35	70	140	350	700	4,704	
	Total Employment	414,136	20,368	14,861	19,591	41,545	31,640	42,000	43,400	45,500	155,231	

Figure 8 Share of Total Employment by Size Category

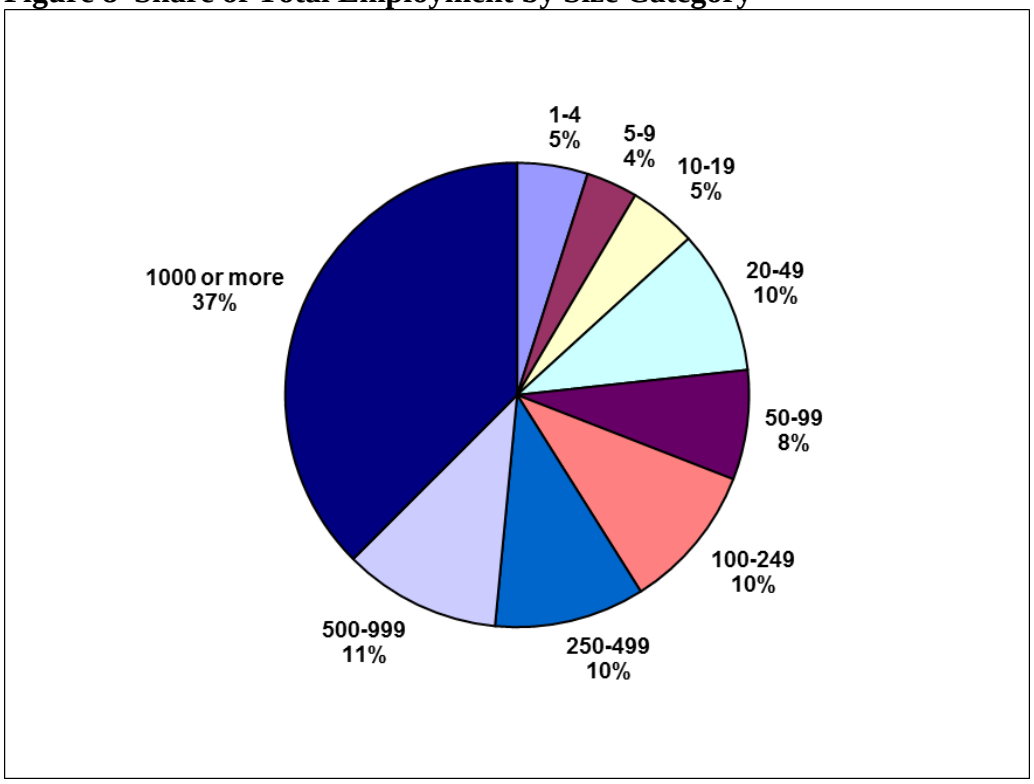
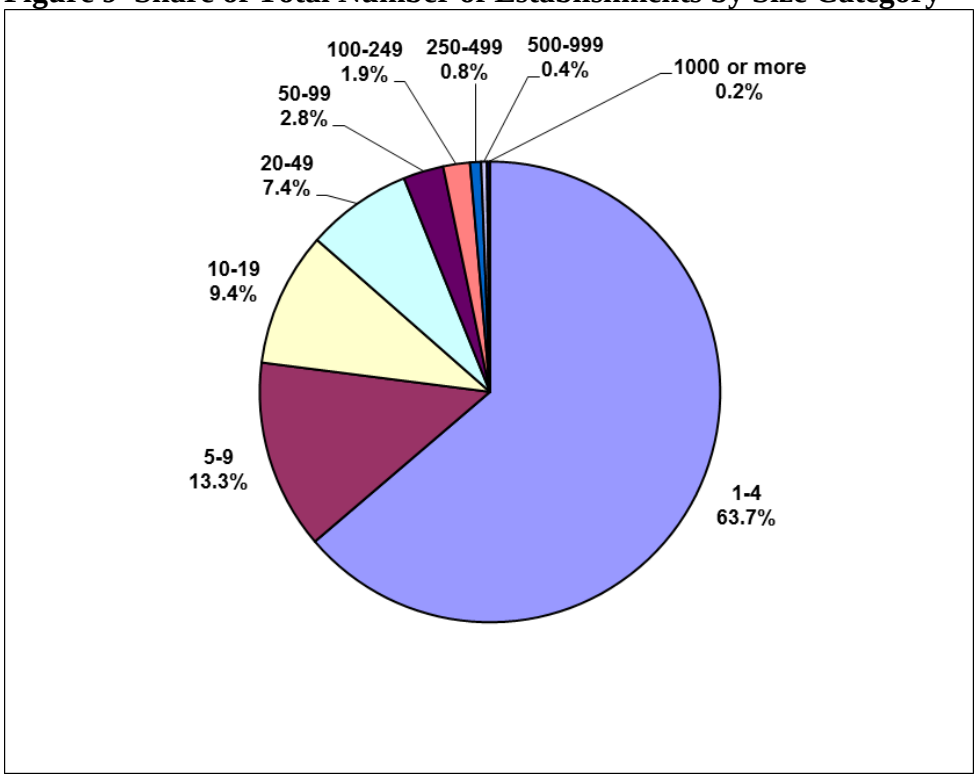


Figure 9 Share of Total Number of Establishments by Size Category



University and Federal Research

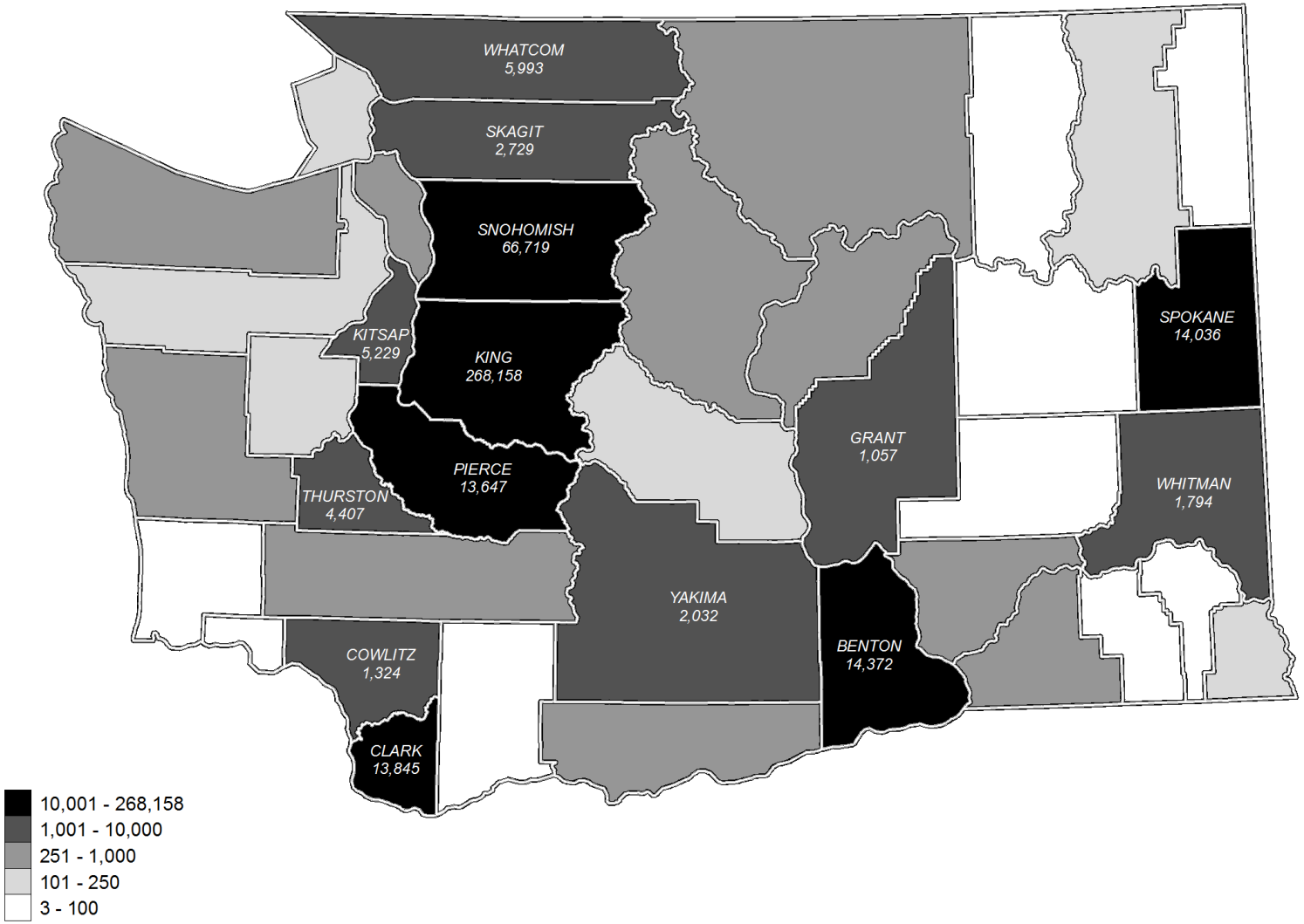
The historical trends described in this section, and the U.S. maps showing the concentration of technology-based employment, exclude employment in university and federal research organizations due to a lack of historical information on these entities. The University of Washington and Washington State 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; their Washington intermediate purchases and labor income percentages are similar to sector 44 in the 2007 Washington input-output model (this sector includes architecture & engineering, specialized design, computer systems design, and scientific research & development).

It is estimated that 11,531 people were employed at university and federal research establishments in 2013, as measured on an FTE basis. At the UW, grant and contract awards have expanded significantly over time, rising from $179 million in 1975 to $531 million in 2013 (as measured in constant 1982-1984 dollars). Grant and contract expenditures at the UW were $1.362 billion in fiscal year 2013, of which $806 million was for research (UW 2013). The balance of these grant and contract funds were obligated for training, fellowships, and other activities (including institutes and conferences, and are not included in this study). The UW is currently the 2nd largest university recipient of federal research funding in the U.S. and the largest recipient among public institutions.

Distribution of Technology-Based Jobs in Washington State

While employment in technology-based industries is strongly concentrated in the Seattle-Everett metropolitan area (where aerospace and technology-based service employment is primarily located), there are firms located in every county in the state. Figure 10 shows the distribution of employment in 2013. Outside of King and Snohomish counties, there are also relatively large numbers of employees in Benton (14,372), Clark (13,845), Pierce (13,647), and Spokane (14,036) counties. Fourteen counties have at least 1,000 persons employed in technology-based industries. Appendix VI contains estimates of technology-based employment for all 39 counties in Washington State.

Figure 10 Technology-Based Employment by County



Source: Washington State Employment Security Department, supplemented with estimates for UW and WSU research, NOAA, and Keyport

Summary

Washington's technology-based industries have grown substantially in the past three decades, such that in the aggregate they now represent 13.9% of total employment (including university research and federal employment at Keyport and NOAA). 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 describes in detail, these industries now represent a substantial component of Washington State's economic base.

IV. Economic Impact Analysis

While technology-based industries employ more than 460,000 people in Washington, there are broader impacts on our economy beyond direct employment. These larger "multiplier" effects occur as a result of businesses within these industries selling their goods and services outside the state, making intermediate purchases within the state, and providing payments to employees in the form of wages and other labor income, a large portion of which is spent on other goods and services within the state economy.

To calculate these larger impacts, the Washington State input-output model was used, which provides 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 2013 (Beyers and Lin 2012). 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

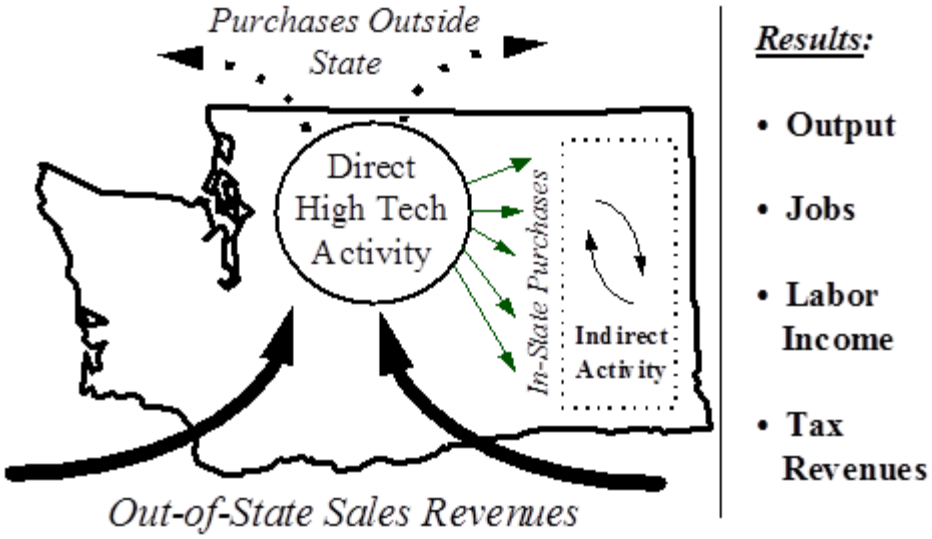
Washington State has invested in the construction of eight regional input-output models beginning in 1963, with the latest model released for the year 2007. These models describe where Washington industries sell their products and where they purchase the inputs needed to make their products. The structural relationships contained in these models are used to estimate the indirect impacts associated with industrial production. The models are divided into "sectors," which have distinctive patterns of inputs, or purchases of goods and/or services regionally. These distinctive purchasing patterns lead to varying multipliers. The widespread application of regional input-output models to impact analyses stems from their ability to pinpoint these differing levels and patterns of impact by industry.

Figure 11 is a schematic that describes the general structure of a regional input-output model. Demands for the products or services of individual industries lead to the direct purchase of inputs to make products and services. These direct purchases are made from suppliers located inside Washington State but are also procured in non-Washington markets. For example, Boeing imports all of the airframes for the 737 airplane from

plants located in Kansas, but they also purchase some services and manufactured goods in Washington State and make large payments to their labor force.

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

Figure 11 Schematic of the Washington State Input-Output Model



Impact Results

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 (wages and supplements) 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 11. Details of this computational process are discussed in Appendix II.

Results of the impact analysis are presented first in the aggregate and then with more detail related to particular segments of technology-based industries in Washington State. Table 9 presents direct and aggregate impact results. Some 460,242 jobs, $221 billion in sales, $802 million in taxes, and $55 billion in labor income were directly

generated by technology-based industries in Washington State in 2013.[9] These values increase significantly once the indirect effects are added from the input-output model calculations. Direct and indirect employment impacts total 1,381,917 jobs across all industries in the Washington economy; overall impacts equal $370.3 billion in sales, with $102.8 billion in labor income. The aggregate level of state sales and use, business and occupation (B&O), and local sales and use taxes are estimated to be $6.9 billion.[10] Later in this section, these large impacts are disaggregated into the contributions of individual sectors.

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

Table 9 Direct and Total Economic Impacts of Technology-Based Industries

	$ in Millions	% Change from 2012 Study in Nominal $
Direct Impacts		
Sales	$220,666	-4.5%
Employment	460,242	6.0%
Labor Income	$55,231	34.5%
Taxes	$802	4.0%
Total Cumulative Impacts		
Sales	$370,342	0.2%
Employment	1,381,917	-4.1%
Labor Income	$102,834	19.9%
Taxes	$6,919	12.8%
Multipliers		
Sales	1.68	
Employment	3.00	
Labor Income	1.86	

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

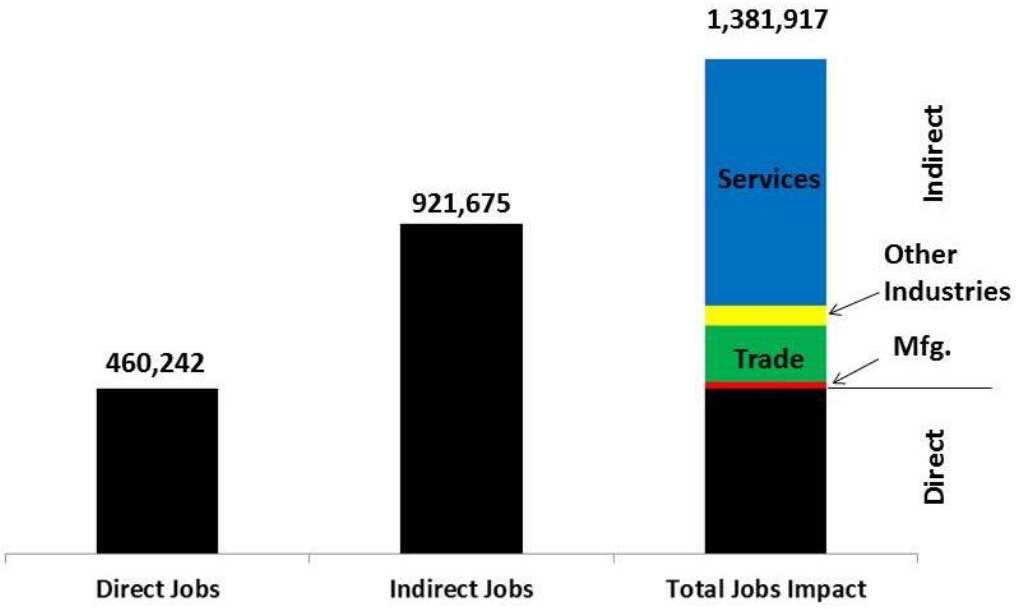
Of the 921,675 indirect and induced jobs created in the Washington economy, some 17,865 of these are in manufacturing, 158,779 are in retail and wholesale trade, 688,757 are in services, and 56,274 are in other industries. The indirect and induced jobs

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

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

reported in Figure 12 are a summary of the job impacts calculated for each of the 52 sectors contained in the Washington State input-output model. 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,[11] and other industry[12] sectors in the input-output model.

Figure 12 Total Direct and Indirect Employment Impacts



The data reported in Table 9 indicate differences in direct and indirect impacts from the 2012 Technology Alliance economic impact study. These differences are related to several factors. First, the 2012 study utilized the 2002 Washington State Input-Output Model to calculate economic impacts, while the current study utilized the 2007 Washington State Input-Output Model. Multipliers in these two models are not the same; most significantly there are changes in labor productivity between these two models that contributed to a decline in employment multipliers. Second, the mix of industries in the current study and in the 2012 study are not the same, leading to different aggregate economic impacts. Third, direct labor income per employee in the current study is well above that estimated in the 2012 study. This increased level of labor income may be related to the recovery of Washington industries from the Great Recession. Increased labor income translates in the impact estimates into increased personal consumption

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

expenditures, which stimulates overall sales, taxes, and labor income. It is not possible to disentangle the contribution of each of these trends to the changes reported in Table 9 for direct and total cumulative impacts.

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

Table 10 Key Indicators for Technology-Based Industries

	Employment Multiplier	Labor Income Per Job	% In State Purchases	% Out of State Sales
Manufacturing				
Aerospace & Motor Vehicle Parts	2.63	$122,593	8.3%	97.0%
Machinery and Computer & Electronic Products	4.22	103,812	37.4%	90.5%
Petroleum & Coal Products	16.79	159,352	17.9%	41.7%
Chemicals	2.80	77,570	18.3%	87.3%
Services				
Software, Data Processing, Other Information Services	4.10	173,390	15.9%	86.0%
Computer Systems Design	2.47	108,603	14.4%	70.1%
Telecommunications	4.29	114,182	32.2%	18.6%
Commercial Equipment Merchant Wholesalers	2.78	119,631	15.3%	27.6%
Electronic Shopping & Mail-order Houses	2.69	108,765	19.7%	87.3%
Scientific Research &Development	2.76	122,646	14.4%	70.1%
Architecture & Engineering and Management, Scientific & Technical Consulting	2.10	85,398	11.3%	70.1%
Management of Companies & Enterprises	2.44	129,658	8.0%	57.0%
Travel Arrangement & Reservation Services	2.51	121,717	8.8%	18.5%
Remediation & Other Waste Management Services	3.53	96,681	35.7%	62.6%
University & Federal Research	2.26	91,280	21.6%	86.4%
All Technology-Based Industries	**3.00**	**120,005**	**16.8%**	**70.1%**
Other Washington Industries	2.45	53, 111	28.1%	27.7%

Technology-based industries have higher employment multipliers than other industries in the Washington economy, and have a level of labor income per job that is more than double the average of other industries in the Washington economy. Technology-based industries are also much more export-oriented than other industries in the Washington economy, and they rely in imports from other regions to a greater extent than other Washington industries. The estimates of in-state purchases and out-of-state sales in Table 10 are based on data for these industries from the 2007 Washington State input-output model. Indicators for individual technology-based industries will be discussed in the next sections of this report.

Table 11 presents summary impacts of technology-based business activity by sectoral group. This table is followed by a brief discussion of the impacts of each sector. Total impacts are as reported in Table 9. Four measures of impact are contained in Table 11. The sales impact figures are a measure of total business activity in the Washington economy related to each technology-based industry. The employment and labor income figures for each technology-based industry are the total estimated direct plus indirect and induced jobs and labor income generated in the Washington economy in the year 2013. The tax impacts in Table 11 are the combination of business and occupation plus sales taxes generated in Washington State due to business activity in each technology-based industry.

Table 11 Summary Impacts by Sector

Manufacturing	Sales ($ Millions)	Employment	Labor Income ($ Millions)	Taxes ($ Millions)
Aerospace & Motor Vehicle Parts	$79,085.5	257,226	$20,081.7	$1,205.4
Machinery and Computer & Electronic Products	23,089.2	97,430	6,715.8	409.4
Petroleum & Coal Products	39,061.2	41,640	2,608.4	303.5
Chemicals Manufacturing	7,179.5	17,771	1,125.4	79.0
Services				
Software, Data Processing, Other Information Services	75,415.8	291,638	23,239.2	1,580.7
Computer Systems Design	22,559.4	120,755	8,874.7	564.7
Telecommunications	31,581.4	98,989	6,929.7	558.3
Commercial Equipment Merchant Wholesalers	8,422.2	36,690	2,789.8	165.8
Electronic Shopping & Mail-order Houses	11,624.5	53,587	3,876.6	230.4
Scientific R&D	11,414.4	54,215	4,128.6	270.0
Architecture & Engineering and Management, Scientific & Technical Consulting	27,496.5	151,734	10,122.2	696.6
Management of Companies & Enterprises	17,853.5	91,069	7,519.6	517.1
Travel Arrangement & Reservation Services	4,158.9	15,829	1,238.6	90.4
Remediation & Other Waste Management Services	6,435.7	27,279	1,743.8	127.7
University & Federal Research	4,963.7	26,065	1,839.9	120.1
All Technology-Based Industries	**$370,341.6**	**1,381,917**	**$102,833.8**	**$6,919.0**

Manufacturing

Aerospace & Motor Vehicle Parts Manufacturing

The aerospace and motor vehicle parts sector generated 257,000 jobs in the Washington economy in 2013, 7.8% of total state employment. Most of the impact of this sector comes from the aerospace sector which employed 95,340 people in 2013; motor vehicle parts had 2,303 employees. As Table 9 indicates, the aerospace and motor vehicle parts sector is strongly focused on markets outside Washington State. The aerospace component of this sector has a history of fluctuation, as the demand for commercial aircraft has boomed or collapsed. The year 2013 corresponded to an expanding phase in the aerospace cycle, with the sector gaining 10,355 jobs in Washington State between 2011 and 2013. However, 2013 wage and salary employment fell short of the 1998 peak level of employment by 17,776 jobs.

While the aerospace and motor vehicles sector accounted for 19% of direct technology-based jobs in 2011, it accounted for a somewhat smaller share (17%) of total job impacts. Although labor income per worker is high in this sector, it has weak backward linkages to other 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 (Beyers & Lin 2012).

Machinery and Computer & Electronic Products Manufacturing

The machinery and computer and electronics industry has a number of segments in the current study. The machinery component is composed of manufacturers of metal working, and engine and turbine and power transmission machinery. The computer and electronics industry includes computer and peripheral equipment; communications equipment; audio and video equipment; semiconductors and other electronic components; navigational, measuring, electromedical and control instruments, and reproducing magnetic and optical media. These industries collectively employed nearly 23,000 people and supported 97,430 total jobs in 2013. The computer and electronics component experienced significant job growth over the 1974-2002 time period (296%), as indicated in Table 5 and Appendix IV, but employment decreased 12% between 2007 and 2011.

This sector is strongly tied to non-Washington markets, exporting 90.5% of its product. Its jobs multiplier of 4.22 is above than the average for all technology-based industries. This sector accounted for 5.0% of technology-based jobs in 2013, and 7.1% of all jobs created statewide by technology-based industries.

Petroleum & Coal Products Manufacturing

The petroleum and coal products industry is dominated in Washington State by petroleum refining, which is done primarily at establishments in Skagit and Whatcom counties. This industry has a very high value of output relative to its employment size (2,608 jobs in 2013), given the current value of crude oil that is its principal input. Data from the 2007 Washington input-output model report that this industry has exports from Washington State of 42% of its value of output, and purchases in-state of 18% of total

purchases. In contrast, only 1.4% of this industry's total purchases are labor income in the state economy, although as Table 10 reports the labor income per job is very high in this industry. Table 10 reports a very high multiplier for this industry—17 total jobs per direct job—probably an unrealistically large multiplier. This result is a byproduct of the input structure in this industry, in which intermediate purchases are larger than payments of labor income (in other industries this relationship is the reverse). This sector has not had much change in employment in recent years, as reported in Appendix V. Table 10 indicates that this industry supported nearly 42,000 jobs in the Washington economy in the year 2013.

Chemicals Manufacturing

The chemicals manufacturing industry 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. Over 6,300 people worked in this industry in 2013, supporting 17,800 jobs in the Washington economy.

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

This industry has lower wages than all technology-based sectors (see Table 10), and a slightly lower employment multiplier than all technology-based industry. The chemicals industry is strongly focused on markets outside Washington State, selling 87% of its output in external markets. This industry was responsible for 1.4% of the technology-based jobs in Washington State, but supported only 0.5% of the total jobs related to technology-based industries, due to its relatively low labor income per employee, and relatively weak purchases level in the Washington economy.

Services

Software Publishers, Data Processing, and Other Information Services

These industries contain establishments primarily engaged in computer software publishing and reproduction; establishments primarily engaged in providing infrastructure for hosting or data processing services; and other information services. These establishments may provide specialized hosting activities, such as web hosting, streaming services or application hosting; provide application service provisioning; or may provide general time-share mainframe facilities to clients. Data processing establishments provide complete processing and specialized reports from data supplied by clients or provide automated data processing and data entry services. Other information services is dominated by employment in internet publishing and broadcasting, but also includes news syndicates, libraries, and other information services.

These industries directly employed 71,091 people, with a relatively high job multiplier of 4.10. They supported 291,638 jobs in the Washington economy in 2013, or 8.8% of total state employment. The high multiplier is related to the high labor income per worker in this sector, estimated to be $173,390, or more than two and one-half times the state average labor income per job. These industries accounted for 15.4% of technology-based jobs, and through its relatively high multiplier, it was responsible for 21.1% of total jobs created by technology-based industries in Washington.

This sector has very strong out-of-state sales (86%), and makes in-state purchases at a level similar to all technology-based industries. Reclassifications from the old SIC code to NAICS and redefinitions of NAICS codes make it difficult to estimate growth of this sector using consistent definitions. However, Table 5 reports growth under the SIC definition of 1,239% from 1974 to 2002, while Appendix V reports a quadrupling of employment in software publishers and data processing and related services from 1998 to 2013.

Computer Systems Design & Related Services

This industry includes establishments providing custom computer programming services, computer integrated systems design, computer facilities management, and other computer related services. Appendix V reports that this industry has had a strong record of growth since 1998 (160.6%). Before the change from the SIC to the NAICS classification system, this industry was part of the computer services industry (SIC 737), which Appendix IV reports had a 13-fold increase in employment from 1974 to 2002. This industry directly employed 48,842 people in 2013, and it generated a total of 120,755 jobs in the Washington economy in 2013. Labor income in this industry is slightly below the tech-industry average, and the employment multiplier (2.47) is also somewhat below the tech-industry average (3.0).

Like software, this industry is strongly export oriented (70%), and buys a modest share of its inputs from the Washington economy (14%). The computer systems design & related services industry accounted for 10.6% of direct technology-based employment in Washington State in 2013, and its impact was 8.7% of total jobs impacts of technology-based industry in 2013.

Commercial Equipment Merchant Wholesalers

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

This industry employed 13,203 people and supported 36,690 jobs in the Washington economy in 2013. The sector earnings per worker similar to all technology-based industry, and a degree of export-market orientation similar to all Washington industries. This sector accounted for 2.9% of technology-based jobs in Washington State, and was responsible for 2.7% of total jobs created due to technology-based industries.

Electronic Shopping & Mail-order Houses

This industry comprises establishments primarily engaged in retailing all types of merchandise using non-store means, including electronic media such as interactive television or the Internet. This industry employed 19,933 people in 2013, or 4.3% of technology-based employment in Washington. It supported 53,587 total jobs, which was 3.9% of the jobs supported by technology-based industry in the state. This industry has grown rapidly, increasing state employment by 258% from 1998 to 2013, as measured by U.S. County Business Patterns.

The 2007 Washington State input-output table included non-store retailing as a sector for the first time. Data from this model indicate that out-of-state sales were 87.3% of total sales, while purchases in the state economy were 19.7% of total purchases. Labor income per employee was $108,765, somewhat below the overall technology-based industry average.

The largest employer in this industry is Amazon.com, headquartered in Washington State, which also has fulfillment centers located around the United States and in foreign countries. Amazon's global sales cannot be attributed to its headquarters activity; it is unknown what the percentage of sales filled by this company's Washington establishments are shipped to customers located in the state. It is also unknown what percentage of overall Amazon and other electronic shopping and mail order house employment is classified in this industry, as opposed to other industries such as NAICS 55 (management of companies and enterprises), or NAICS 5415 (computer systems design).

Telecommunications

The telecommunications industry is composed of establishments providing wired, wireless, and satellite telecommunications; telecommunications resellers; and other telecommunications services. Changes in NAICS code definitions made in 2007 have altered where some telecommunications activities are classified. Due to these reclassifications there is a lack of historical data for this industry. The current industry had 23,067 employees in 2013 which was 5.0% of all technology-based employment in Washington State. This industry has a relatively high jobs multiplier, accounting for 98,989 jobs or 7.2% of total jobs supported by technology-based industry in the Washington economy.

The Washington input-output table reports a low level of out-of-state sales for this industry, only 18.6%, making this sector the most strongly linked to the Washington economy of any technology-based industry. The industry's level of in-state purchases was higher than that of other technology-based industries. Labor income per worker was slightly below the technology-based industry average.

Architectural & Engineering Services and Management, Scientific & Technical Consulting

This industry includes establishments engaged in architecture, engineering, and related services, as well as providing management, scientific, and technical consulting services. Over 72,000 people were employed in these industries in 2013, and the sector supported almost 151,734 jobs in the Washington economy. Earnings in this sector are below the average for all technology-based industries, but well above the statewide average. This sector accounted for 15.7% of all technology-based jobs in Washington State, and it supported 11.0% of the total jobs created by technology-based industries. Market data for this sector show that about 57% of sales are made out-of-state, while 11.3% of purchases were made in-state.

Self-employment in this industry is quite high, accounting for 54% of the total number of self-employed workers included in this study. Within this industry, 30% of total employment was by the self-employed, compared to 8.8% for all technology-based industries. The lower earnings by the self-employed compared to those on wage and salary employment pulled down the average level of earnings in this industry.

This sector is not comparable to definitions based on the SIC system. Table 5 indicates that engineering, research, and consulting services had strong growth in Washington State between 1974 and 2002, while Appendix IV indicates that architectural and engineering services and management and public relations services have also had strong growth over this time period. Research and testing services were included in this industry grouping in early Technology Alliance studies, but in studies since 2005 that activity is classified separately as scientific research and development services.

Management of Companies & Enterprises

This industry is one that is somewhat problematic for this research project, as it is not clear what type of industrial activity is related to those classified in NAICS 55. In the SIC classification scheme, headquarters were treated as "administrative and auxiliary" establishments, and were reported at the industry division level (such as manufacturing or retail). The NAICS system reclassified these entities into NAICS code 55, with no subdivision into the equivalent of industry divisions found in the SIC system. The following text comes from the U.S. Census Bureau, defining this industry.

> The Management of Companies and Enterprises sector comprises (1) establishments that hold the securities of (or other equity interests in) companies and enterprises for the purpose of owning a controlling interest or influencing management decisions or (2) establishments (except government establishments) that administer, oversee, and manage establishments of the company or enterprise and that normally undertake the strategic or organizational planning and decision-making role of the company or enterprise. Establishments that administer, oversee, and manage may hold the securities of the company or enterprise.
>
> Establishments in this sector perform essential activities that are often undertaken, in-house, by establishments in many sectors of the economy. By consolidating the

performance of these activities of the enterprise at one establishment, economies of scale are achieved.

This industry directly employed 37,362 people in Washington State in 2013, and supported 91,069 jobs in the state economy. It accounted for 8.1% of direct technology-based jobs, and 6.6% of total job impacts. This industry has no self-employment, and average labor income slightly higher than all technology-based industry. The employment multiplier is slightly below the technology-based industry average, because regional purchases in this industry are relatively low (8%) compared to the technology-based industry average (16.8%). The Washington input-output table indicates that export sales in this industry is lower than the technology-based industry average (43%).

Appendix V reports a sharp drop in employment in management of companies and enterprises between 2000 and 2002. This is likely related to reclassifications of establishments in the wake of the 2002 NAICS redefinitions. Unfortunately, there are no statistical reports available that document these reclassifications. It is likely that some employment of major technology-based Washington State businesses, such as Amazon and Microsoft, is classified in this industry, but it is not possible to define the magnitude of this activity.

Scientific Research & Development

This industry 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 20,000 people worked in this industry statewide in the year 2013, and it supported a total of over 54,000 jobs. Earnings are similar to the average for technology based industries. This industry accounted for 4.3% of technology-based industry employment, and was the source of 3.9% of the jobs supported in the Washington economy by technology-based industries.

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

Table 6 reports a doubling of wage and salary employment in this industry since 1998, when the NAICS definition measurement was first reported. This industry has about 70% of its revenues from outside of the state; this is likely a conservative estimate, as a substantial fraction of the activity in this sector takes place on federal account 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 this industry.

Travel Arrangement & Reservation Services

This industry appears for the first time in this analysis of technology-based industry in the Washington economy. It is composed of travel agencies, tour operators, convention and visitors bureaus, and other travel arrangement and reservation services. The majority of employment is found in travel agencies, including the large online travel company Expedia. Table 6 reports a decline in wage and salary employment in this industry since 1998, but also reports considerable year-to-year volatility in estimates of employment in this industry. Approximately 10% of the employment in this sector is self-employment, as reported in Table 4.

The travel arrangement and reservation services industry accounted for 1.4% of total technology-based employment in Washington State in 2013, and resulted in 1.1% of total jobs supported by technology-based industry in the same year. Earnings in this industry were at the average for technology-based industry. Table 8 reports export sales of only 18.5% for this industry—data based on the broad sector within which this industry is included in the Washington State input-output model. This is likely a very conservative estimate of exports, but no alternative data were available to provide a more realistic estimate of sales outside of the state.

Remediation & Other Waste Management Services

This sector is composed of remediation and other waste management services, including materials recovery, septic tank & related services, and miscellaneous waste management services; it does not include establishments engaged in waste collection. The majority of employment in this industry is in remediation services, related to Hanford cleanup activities.

In 2013, this sector employed 7,735 people, and supported 27,279 jobs in the Washington economy. It accounted for about 1.7% of direct technology-based jobs, and for about 2.0% of total job impacts. Table 10 reports 62.6% export sales for this industry. This figure was derived by assuming that the federal government provided the revenue for Hanford cleanup work in Benton County. ESD provided an estimate of 4,131 people employed in this industry in Benton County, which is 53% of the statewide total in this industry. It was assumed that the balance of employment in this industry had exports as reported in the Washington input-output model for the sector that includes NAICS 5629, which was 19.8%. The export percentages for other industries in Table 10 are directly from the 2007 Washington State input-output table; the adjustment just described was made to better represent exports from this industry.

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 Division Keyport. No historical data are available for this sector. The definition of this sector differs from the first three

Technology Alliance studies, which included other components of research activity along with university and federal research. In the 2005, 2008, 2010 studies, as well as the current study, these university and federal research activities are considered to be a separate industry.

The wage level is lower than other technology-based industries, creating low multipliers. This is due to the inclusion of university research in this sector, in which a large number of graduate students are paid a relatively modest level of income compared to research staff and faculty. About 2.5% of the jobs in technology-based industries are in this sector, and they support around 1.9% of total jobs related to technology-based industry. Almost all of the revenue to this sector is derived from out-of-state sources, primarily from the federal government.

V. Conclusions

This study describes the growing importance of technology-based industries in the Washington economy. In 2013 these industries employed 460,242 people, and supported a total of 1,381,917 jobs in the state economy. Through multiplier effects, technology-based industries were responsible for 42% of Washington's 3.3 million wage and salary and self-employed jobs in 2013. The share of Washington employment accounted for by private sector technology-based industries has risen from 6.7% to 14.1% from 1974 through 2013, a trend that suggests that the total impact of technology-based employment on the state 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 $2.43 billion in 2013. (Local B&O tax collections were not estimated in this study.) Sales and use tax revenues to the State of Washington due to technology-based industries (inclusive of indirect effects) were estimated to be $3.07 billion; an additional $1.42 billion in local sales and use taxes were generated to local governments, for a total tax impact of $6.92 billion.

Technology-based industries directly and indirectly generated a total of $102.8 billion in labor income in 2013, which is 47.5% of total labor income earned in Washington that year. Thus, from the multiple perspectives of job creation, tax revenues, and labor income, technology-based industries account for about 42%-48% of total activity in the state economy[13]

From a national perspective, Washington State is a center of technology-based employment and R&D activity. The concentration of employment in the sectors covered by this study places Washington 1st in the nation, and 4th in R&D funding indexed against Gross State Product. Washington has increased its concentration of technology-based

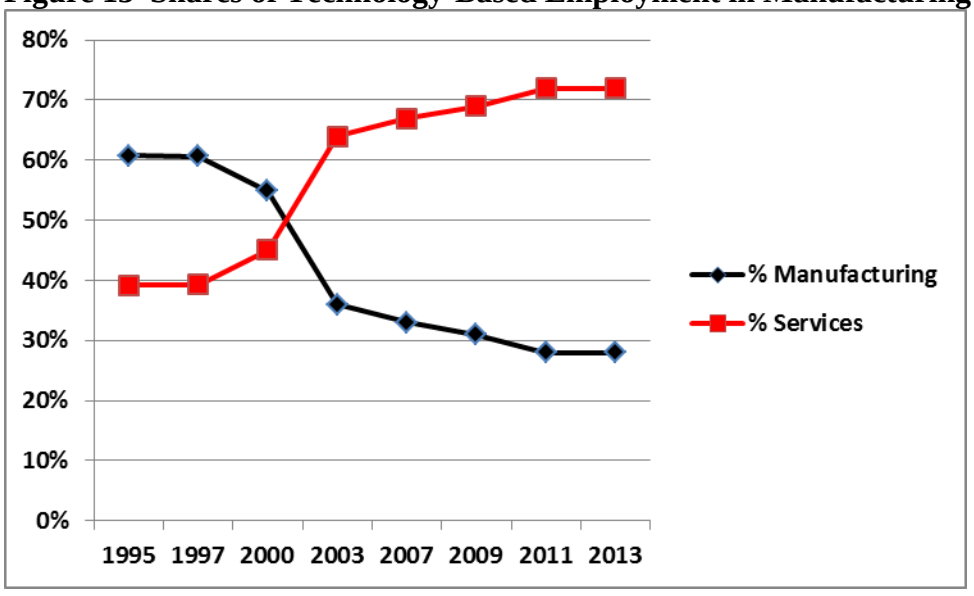
[13] A direct measure of their contribution to gross state product was not undertaken in this study, primarily because the output of these sectors enters export markets, while gross state product is predominantly composed of sales to regional components of final demand (consumption, investment, and state and local government outlays).

industries over time, from 10% above the national average in 1985 to 49% above it in 2013.

The change in the definition of technology-based industries due to the shift from the SIC system to NAICS makes it difficult to estimate growth rates for many Washington technology-based industries compared to the nation as a whole over the long run. Statistics for the SIC-based system presented in this report (Table 5 and Appendix IV) 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. Statistics from the NAICS based system (Table 6 and Appendix V) also report strong growth.

As Washington's technology-based employment has grown, it has also become more diversified. In 1974, 57% of technology-based employment was in aerospace; by 2013 this share had fallen to 21%. 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 software and other computer services; scientific research and development; architectural and engineering services; and management, scientific, and technical consulting services. Growth in these services industries should help the Washington economy continue the long-term diversification of its technology-based employment. Figure 13 documents the changing shares of manufacturing and services employment across the eight studies of technology-based industry conducted by the author for the Technology Alliance.

Figure 13 Shares of Technology-Based Employment in Manufacturing and Services



Technology-based industry jobs are high-wage, full-time types of work. In 2013 the average level of labor income per job in technology-based industry in Washington State was $120,005, which is 113% higher than the average level of labor income per

worker in other industries in Washington State. This high wage level is prevalent in most technology-based industries, and it leads to relatively high impact levels stemming from the expenditure of this income.

Technology-based industries are also strongly focused on external markets, selling at least 70% of their output to clients located out-of-state. This level of exports is much higher than other industries in the Washington economy (28%), 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-based industries and 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, including the investment in productive capital needed to support their production process. The research and development intensity of these sectors also has a long-term impact on new business formation, as new businesses spin out of existing firms and research organizations. In industries such as biotechnology, this process has important impacts as firms move from the research to the commercialization phase of the production process. University research also results in new business formation that has lasting economic impacts on the state economy. Again, this study has not quantified these effects and is therefore a conservative view of the larger impacts of technology-based activities in the state economy.

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

The use of the Internet for business-to-business sales and purchases is burgeoning, and the application of information technologies in a wide array of industries has now been recognized as fueling an increase in the productivity of American industry (Atkinson and Stewart 2012). 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 include many of the technology-based industries covered by 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 use a different basis

for defining industries included in an analysis, such as those just mentioned, that could find an even larger economic impact than measured in this study.

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

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

A continuous stream of research focuses 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 definition of R&D related work as its basis for defining the scope of the industries included in this and the previous Technology Alliance economic impact studies. In this appendix several recent studies are discussed, to highlight the diversity of approaches to defining technology-based or high tech industry.

TechAmerica

TechAmerica was formed by the merger of the American Electronics Association, Information Technology Association of America, Government Electronics and Information Association, and the Cyber Security Industry Affairs Association. They argue that they are a leading voice for the Information and Communications Technology (ICT) industry in the United States. TechAmerica continues to produce documents that were previously produced by the American Electronics Association (AEA) at the national, state, and metropolitan area on industries it deems to be high-tech (TechAmerica 2013). TechAmerica states "To be included in TechAmerica Foundation's core definition of tech, an industry must be a maker/creator of technology, whether products or services. The definition does not include wholesale or retail trade, industries that are primarily dedicated to selling technology products as opposed to making/creating the technology." (TechAmerica 2013, p. 109). Their definition includes computers and peripheral equipment, communications and consumer electronics, electronic components, semiconductors, space and defense systems, measuring and control instruments, electromedical equipment, photonics, internet and telecommunications services, software publishers, computer systems design and related services, engineering services, R&D and testing laboratories, and computer training. Using this definition, TechAmerica publishes documents such as Cyberstates, which provides a state-by-state national assessment of measures such as employment, earnings, exports, R&D, and venture capital investment (TechAmerica 2013). They also issue on-line press releases that highlight activity levels in each state, provide estimates of high-tech in 60 major metropolitan areas (cybercities), and are producing measures of high-tech international trade for the states. The TechAmerica 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 (191,000 jobs in Washington State versus the estimate of 460,242 contained in this study).

Bureau of Labor Statistics

The Bureau of Labor Statistics reviewed the definition of high-technology employment in a paper published in 1999. Hecker (1999) revisited the widely cited 1983 evaluation of these definitions by BLS and, using the considerable resources at the disposal of the federal statistical agencies, embraced a definition very similar to that used in the Technology Alliance economic impact studies. He writes, "For this analysis, industries are considered high tech if employment in both research and development and

in all technology-oriented occupations accounted for a proportion of employment that was at least twice the average for all industries in the Occupational Employment Statistics survey " (Hecker 1999). The paper includes a useful comparison of the industries included in this definition (they are the ones used in the first three TA studies), as well as in a number of other recent and older studies, including many reviewed in the earlier TA studies. Hecker recently revisited the definition of high-tech, given the shift in measurement to the NAICS system (Hecker 2005). His NAICS definitions are very similar to those used in this study.

National Science Foundation

The National Science Foundation (NSF) presents annually Science and Engineering Indicators, a diverse set of measures related to NSF's mission. NSF states: "*Science and Engineering Indicators* (SEI) is first and foremost a volume of record comprising the major high-quality quantitative data on the U.S. and international science and engineering enterprise. SEI is factual and policy neutral. It does not offer policy options, and it does not make policy recommendations." (NSF 2014). SEI has eight chapters, among which is a set of state indicators. Relevant to this Technology Alliance economic impact study are data on the science and engineering labor force, research and development spending, and the state indicators. These data were used in this study to document the level of doctoral employment in Washington industries compared to the U.S. as a whole.

NSF has used the same definition of occupations as used in the current study to define technology-based industry, but in 2012 it changed this definition. The 2012 edition of SEI it wrote: "High-technology industries are defined as those in which the proportion of employees in technology-oriented occupations is at least twice the average proportion for all industries. High-technology occupations include scientific, engineering, and technician occupations that employ workers who generally possess in-depth knowledge of the theories and principles of science, engineering, and mathematics at a post-secondary level." NSF 2012, Ch 8, Employment in high-technology industry establishments as a percentage of total employment. Table I-1 below reports the list of industries included in the 2014 NSF definition, most of which are included in the current Technology Alliance study.

2007 NAICS codes that constitute high-technology industries – NSF definition

NAICS code	Industry	In Current TA Study
1131, 1132	Forestry	
2111	Oil and gas extraction	
2211	Electric power generation, transmission, and distribution	
3241	Petroleum and coal products manufacturing	x
3251	Basic chemical manufacturing	x
3252	Resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing	x
3253	Pesticide, fertilizer, and other agricultural chemical manufacturing	x
3254	Pharmaceutical and medicine manufacturing	x
3255	Paint, coating, and adhesive manufacturing	x
3259	Other chemical product and preparation manufacturing	x
3332	Industrial machinery manufacturing	

3333	Commercial and service industry machinery manufacturing	
3336	Engine, turbine, and power transmission equipment manufacturing	x
3339	Other general purpose machinery manufacturing	
3341	Computer and peripheral equipment manufacturing	x
3342	Communications equipment manufacturing	x
3343	Audio and video equipment manufacturing	x
3344	Semiconductor and other electronic component manufacturing	x
3345	Navigational, measuring, electromedical, and control instruments manufacturing	x
3346	Manufacturing and reproducing magnetic and optical media	x
3353	Electrical equipment manufacturing	
3364	Aerospace product and parts manufacturing	x
3369	Other transportation equipment manufacturing	
4234	Professional and commercial equipment and supplies, merchant wholesalers	x
4861	Pipeline transportation of crude oil	
4862	Pipeline transportation of natural gas	
4869	Other pipeline transportation	
5112	Software publishers	x
5171	Wired telecommunications carriers	x
5172	Wireless telecommunications carriers (except satellite)	x
5174	Satellite telecommunications	x
5179	Other telecommunications	x
5182	Data processing, hosting, and related services	x
519130	Internet publishing & broadcasting and web search portals	x
5211	Monetary authorities, central bank	
5232	Securities and commodity exchanges	
5413	Architectural, engineering, and related services	x
5415	Computer systems design and related services	x
5416	Management, scientific, and technical consulting services	x
5417	Scientific research and development services	x
5511	Management of companies and enterprises	x
5612	Facilities support services	
561312	Executive Search Services	
8112	Electronic and precision equipment repair and maintenance	

Office of Technology Policy

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

based on the 1997 NAICS codes, while the current Technology Alliance study has used the 2007 NAICS codes. The industry list used by the Office of Technology Policy is similar, but not identical, to the classification used in this study. This office was abolished in 2007.

Milken Institute

The Milken Institute has produced a variety of reports that have a high-tech component to them. This organization describes itself as follows: "A nonprofit, nonpartisan economic think tank, the Milken Institute works to improve lives around the world by advancing innovative economic and policy solutions that create jobs, widen access to capital, and improve health" (Klowden, and Wolfe 2013). The Milken Institute publishes periodically a report entitled "State Technology and Science Index," based on 79 different measures in the 2013 edition, which is benchmarked against the year 2012. These measures span R&D inputs, risk capital and entrepreneurial infrastructure, human capital capacity, technology and science workforce, and technology concentration and dynamism. The latter includes measures similar to those included by the Office of Technology Policy. Milken does not specifically identify the industries included in their technology concentration and dynamism indicator, but it indicates that it uses Bureau of Labor Statistics, Census Bureau and data that it develops in constructing these indicators. Washington ranked 3rd on the technology and science workforce indicator and 2nd on the technology concentration and dynamism index in 2012. 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 was 5th in the 2013 edition of the State Technology and Science Index, up from 6th in 2010.

The 2012 State New Economy Index

This latest version of the State New Economy Index by Atkinson and Stewart has been published by the Information Technology and Innovation Foundation, with support from the Kauffman Foundation (Atkinson and Stewart 2012). They developed a set of indicators for the states, and then focused on economic development strategies for the new economy. High-tech industry is defined as by the TechAmerica, plus the addition of biomedical sectors based on work of the BLS (Atkinson and Stewart 2012). Washington State ranked 3rd in 2012 in this analysis, down from 2nd in the 2010 analysis, but up from Washington's 4th position in the 1999, 2002, and 2007 State New Economy Index measures. This analysis used 26 measures in 2012, many of which are similar those used in the Milken Institute analysis.

Index of the Massachusetts Innovation Economy

This document is not a study of technology-based industry as such, but it has many parallel considerations to information reported in this document, and in the State New Economy and Milken Reports. A set of peer states were selected—Washington is not one of them—and a set of indicators of performance of Massachusetts versus these peers is presented (The Innovation Institute and Massachusetts Technology Collaborative 2014). Industry clusters are defined, although it is not clear how, and these include aspects of technology-based industries as defined in this report, but also other industries.

The report has 24 indicators of performance, including some identical to those used in this study (such as R&D indexed to a per capita or per $ of GDP). Indicator categories include economic impact, research, technology development, business development, capital, and talent. The report is suggestive of directions for policy, but does not directly articulate recommendations. Massachusetts has a stronger concentration of research and development activity as a share of GDP than Washington, but the location quotient maps presented earlier in this report indicate that Washington's concentration of technology-based industry is greater than found in Massachusetts, using the Technology Alliance's definition of technology-based industry.

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, 2002 and 2007. 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 economic impact study is based on work completed in 2011-2012 by a team of Washington State government staff and Beyers (Beyers and Lin 2012).

Input-output models decompose regional economies into "sectors"–groups of industries with a common industrial structure. At the heart of these models are "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 was published in 2012 by the Washington State Office of Financial Management. The model has 52 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, 2011

NAICS	Industry	CBP	Nonemployer	Combined
324	Petroleum & Coal Products	0.685	0.487	0.694
325	Chemicals Manufacturing	0.381	0.902	0.396
3335	Metalworking Machinery Manufacturing	0.611	1.197	0.630
3336	Turbine & Power Transmission Equipment	0.139	0.258	0.144
334	Computer & Electronic Products Manufacturing	0.978	1.478	1.002
3363	Motor Vehicle Parts Manufacturing	0.197	0.085	0.200
3364	Aerospace Manufacturing	7.730	3.148	7.854
4234	Commercial Equipment Merchant Wholesalers	1.131	1.053	1.151
4541	Electronic Shopping & Mail-order Houses	1.109	1.600	1.204
5112	Software Publishers	7.134	2.894	6.886
517	Telecommunications	1.097	0.917	1.111
518	Data Processing & Related Services	1.496	1.046	1.469
519	Other Information Services	1.696	1.275	1.577
5413	Architectural & Engineering Services	1.268	1.332	1.279
5415	Computer Systems Design & Related Services	1.057	1.580	1.137
5416	Management, Scientific & Technical Consulting	0.942	1.346	1.062
5417	Scientific Research & Development Services	1.204	1.355	1.228
55	Management of Companies	1.484	0.000	1.514
5615	Travel Arrangement & Reservation Services	1.490	0.884	1.416
5629	Remediation & Other Waste Management Services	2.277	0.963	2.244
	Total All Tech-Based Industry	1.488	1.399	1.491

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

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

Sources: Washington State Employment Security Department; U.S. County Business Patterns; The Boeing Company; estimates by author

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

Appendix V Growth of Employment in Technology-Based Industries in Washington State, 1998-2013 (excluding federal & university research and self-employed), NAICS Definition

NAICS		% Change 1998-2013	2013	2011	2009	2007	2005	2002	2000	1998
	Manufacturing									
324	Petroleum and Coal Products	20.9%	2,463	2,370	2,606	2,444	2,314	2,726	2,030	2,037
325	Chemicals	15.4%	6,140	5,824	5,796	5,919	5,202	5,798	4,842	5,320
3335	Metalworking Machinery	25.2%	2,222	1,816	2,028	2,270	1,928	1,205	1,850	1,775
3336	Engine, Turbine & Power Transmission Machinery	144.3%	342	278	204	140	241	192	140	140
334	Computer & Electronic Products Manufacturing	-58.1%	19,984	19,477	21,539	22,576	22,003	25,948	45,554	47,720
3363	Motor Vehicle Parts Manufacturing	-18.5%	2,299	1,749	1,736	2,334	2,812	2,688	3,024	2,821
3364	Aerospace	-15.7%	95,186	84,831	82,932	78,667	65,096	75,667	93,221	112,962
	Services									
4234	Commercial Equipment Merchant Wholesalers	NC	12,994	13,397	14,195	14,277	13,774	14,399	NC	NC
4541	Electronic Shopping & Mail-order Houses	258.3%	16,964	11,154	8,906	10,833	9,614	9,586	6,613	4,734
5112	Software Publishers	335.9%	53,224	51,197	51,468	47,240	41,122	35,782	27,022	12,209
517	Telecommunications	-25.4%	22,542	24,389	25,741	26,140	25,717	30,988	32,975	30,200
5182	Data Processing & Related Services	132.9%	5,154	4,338	4,030	4,005	2,816	1,885	2,767	2,213
5191	Other Information Services	NC	8,634	6,994	4,515	NC	NC	NC	NC	NC
5161	Internet Publishers & Broadcasters	NC	NC	NC	NC	1,910	1,743	1,149	NC	NC
5172	Wireless Telecommunications	NC	NC	NC	NC	13,200	12,403	12,828	NC	NC
518	ISP & Data Processing	NC	NC	NC	NC	4,018	4,529	4,492	NC	NC
5413	Architectural & Engineering Services	16.2%	33,197	34,431	35,771	34,367	31,000	29,701	28,888	28,564

Appendix V, continued

		% Change 1998-2013	2013	2011	2009	2007	2005	2002	2000	1998
5415	Computer Systems Design	160.6%	40,086	35,751	31,927	28,398	21,507	22,821	24,697	15,381
5416	Management, Scientific & Technical Consulting Services	90.8%	17,349	14,905	12,942	11,436	9,870	8,239	11,685	9,093
5417	Scientific Research & Development Services	98.8%	18,865	20,027	19,117	18,765	18,090	16,354	10,936	9,489
55	Management of Companies & Enterprises	-30.3%	37,362	32743	33,560	34,479	33,313	30,186	47,774	53,616
5615	Travel Arrangement & Reservation Services	-32.5%	5,673	7,120	8,243	6,396	6,237	6,633	8,531	8,399
5629	Remediation & Other Waste Management Services	42.2%	7,607	9,590	8,665	8,319	7,918	7,640	6,594	5,350
	Total	NC	408,285	382,381	375,921	378,133	339,249	NC	NC	NC
	Estimate for 1998 through 2002	16.0%					At Least	346,907	359,143	352,023

Sources: Washington State Employment Security Department, U.S. Census Bureau County Business Patterns

Appendix VI Washington Technology-Based Employment by County (Excludes Self-Employed)

Alphabetical		By # of Jobs	
Adams	47	King	268,158
Asotin	115	Snohomish	66,719
Benton	14,372	Benton	14,372
Chelan	716	Spokane	14,036
Clallam	449	Clark	13,845
Clark	13,845	Pierce	13,647
Columbia	3	Whatcom	5,993
Cowlitz	1,324	Kitsap	5,229
Douglas	428	Thurston	4,407
Ferry	53	Skagit	2,729
Franklin	427	Yakima	2,032
Garfield	10	Whitman	1,794
Grant	1,057	Cowlitz	1,324
Grays Harbor	481	Grant	1,057
Island	631	Klickitat	889
Jefferson	180	Chelan	716
King	268,158	Island	631
Kitsap	5,229	Lewis	502
Kittitas	231	Walla Walla	501
Klickitat	889	Grays Harbor	481
Lewis	502	Clallam	449
Lincoln	14	Douglas	428
Mason	230	Franklin	427
Okanogan	258	Okanogan	258
Pacific	84	Kittitas	231
Pend Oreille	54	Mason	230
Pierce	13,647	Stevens	212
San Juan	197	San Juan	197
Skagit	2,729	Jefferson	180
Skamania	84	Asotin	115
Snohomish	66,719	Pacific	84
Spokane	14,036	Skamania	84
Stevens	212	Pend Oreille	54
Thurston	4,407	Ferry	53
Wahkiakum	17	Adams	47
Walla Walla	501	Wahkiakum	17
Whatcom	5,993	Lincoln	14
Whitman	1,794	Garfield	10
Yakima	2,032	Columbia	3

Source: Washington State Employment Security Department

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