

**INDUSTRY SECTOR ANALYSIS OF THE SUPPLY AND DEMAND OF
SKILLED LABOR IN CALIFORNIA**

**A REPORT PREPARED FOR
THE CALIFORNIA COUNCIL ON SCIENCE AND TECHNOLOGY**

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JUNE 30, 1999

**ABOUT THE CCST CALIFORNIA REPORT ON THE ENVIRONMENT FOR
SCIENCE AND TECHNOLOGY**

CCST's California Report on the Environment for Science and Technology (CREST) has analyzed the state's science and technology infrastructure to determine if California has the people, capital investment and necessary state governmental policies to maintain California's leadership in the face of increasing worldwide competition. Through eight individual research projects, CREST analyzes the state's ability to create and use new technology. By facilitating a dialog with policy makers, industry leaders, and academic communities, CCST hopes to enhance economic growth and quality of life for Californians.

ACKNOWLEDGMENTS

The California Council on Science and Technology gratefully acknowledges support from the W. M. Keck Foundation of Los Angeles, CCST's Sustaining Members, and the State of California.

The author is grateful to the assistance provided by Kelly Bedard, Assistant Professor of Economics at Claremont McKenna College in developing this project.

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Industry Sector Analysis of the Supply and Demand of Skilled Labor in California

ISBN 1-930117-06-X

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1. Introduction

By many indicators, California is a leader in science and technology. It is the home of the fabled Silicon Valley and of 48 federal research labs. California inventors receive a disproportionate share of U.S. patents. Yet, this technology leadership could be threatened. California is lagging behind other states in workforce readiness. If California cannot meet industry's demand for skilled labor, it could lose science and technology jobs to other states.

This paper assesses the supply and demand of skilled labor for the science and technology industries of California. Although several recent studies have explored high-tech labor markets, this study differs from this earlier research in several important respects. One, the scope of industries studied is more expansive. Most of the recent research has focused on the market for information technology workers. (Freeman and Aspray, 1999; Lerman, 1998; Information Technology Association of America, 1998) This report examines employment and wages in biotechnology, aerospace, computers and electronics in addition to software and computer related services.¹ It examines employment trends for biological scientists and aerospace engineers as well as for computer programmers.

Much of the earlier research was generated in the context of a political battle over the proposed expansion of the H-1B visa program.² The United States Department of Commerce study, *America's New Deficit*, is one example. Relying heavily on research conducted by the Information Technology Association of America (ITAA, 1998), the Commerce Department summarized trends in employment, wages and vacancy rates for information technology workers. It concluded that the United States is "having trouble keeping up with the demand for new information technology workers." (US Dept. of Commerce, 1998, p1.) As a counterpoint to the ITAA and the Commerce Department, Dr. Robert I. Lerman, a prominent economist at the Urban Institute, testified before Congress that the case for a shortage was "far from conclusive." (Lerman, 1998a & b) The US General Accounting Office reviewed the evidence in the US Department of Commerce study and agreed, citing the need for additional information. (US General Accounting Office, 1998)

This report will not resolve the question of a shortage of information technology workers. It presents evidence

¹ This study is part of a larger project on California's science and technology infrastructure sponsored by the California Council on Science and Technology (CCST). For compatibility with other studies in the project, this paper will use CCST's definition of the science and technology industries of California -- biotechnology and biomedical; software and computer related services and entertainment; computer and electronic equipment; telecommunications; and aerospace.

² Freeman and Aspray offer an excellent discussion of this political context. (Freeman and Aspray, 1999)

that, over time, an unfettered labor market will adjust to a new equilibrium. A primary concern of this report is: will this new equilibrium mean fewer science and technology jobs in California?

Although the information technology labor market has attracted the most attention, a few studies have examined labor market conditions in a more broadly defined high-tech sector. Two articles in the *Monthly Labor Review* examine employment trends in high-tech industries defined on the basis of R&D intensity. (Hadlock, Hecker and Gannon, 1991; Luker and Lyons, 1997) The most recent of the two reports a slow down of employment growth in R&D intensive industries and shift away from manufacturing toward services. The American Electronic Association's annual report card on the US high tech workforce defines high-tech to include electronics as well as information technology. (AEA, 1998)

Two studies of California's high-tech sector have a narrower focus. Allen Scott (1998) examines the multimedia and visual effects labor market in Southern California. The Silicon Valley Joint Venture Workforce Initiative report (A.T. Kearney, 1999) assesses the personnel needs of companies in Silicon Valley.

This report will not try to duplicate these earlier efforts. Instead, it will provide a synthesis of research findings and discuss the implications for the health of California's science and technology. It focuses on four specific questions.

- ◆ What has been the trend in employment and wages?
- ◆ Is there a shortage of skilled labor?
- ◆ Is California's science and technology sector in danger of losing ground to other states?
- ◆ What are the implications for public policy?

The basic findings are summarized below.

- ◆ Despite dramatic employment growth in computer software, science and technology's share of total employment in California has been relatively stable.
- ◆ Signals of a labor shortage (as economists would define it) are mixed. Labor supply is responding to changes in demand.
- ◆ Even though the market works, the new equilibrium may mean fewer high tech jobs in California. California's share of U.S. science and technology employment is slipping.
- ◆ Keeping jobs in California will require increased investment in K-12 education and expansion of opportunities for lifelong learning.

2. Employment Trends

Between 1995 and 1998, employment grew in the science and technology sector, but this sector's share of total employment in California has remained relatively stable. Computer programming and data services is by

far the fastest growing sector while employment in aerospace is contracting.

Figure 1 describes the 1995-1998 percentage change in employment in science and technology industries³ for the United States and Figure 2, for California. Total science and technology employment grew by 15.8% nationally and by 15.6% in California. In 1995, US science and technology industries employed approximately 8.8 million workers; in 1998, approximately 10.2 million.⁴ In California, employment increased from 1.3 million in 1995 to 1.5 million in 1998.

The most dramatic increase in employment occurred in computer programming services. Employment in computer programming services grew by 47% in the United States and by 44% in California. In contrast, total non-farm employment grew by 7.4% nationally and by 9.4% in California over the same period.

However, not all science and technology industries experienced above average employment growth. Employment in communications equipment and in search and navigation increased, but at a rate below the average for all nonfarm employment. Employment decreased in missiles and spacecraft by 9.3% in the United States and by 13.5% in California.

³ The data is from the US Bureau of Labor Statistics (BLS). The BLS classifies industries using the Standard Industrial Classification (SIC) system. The system is hierarchical. Each two-digit category consists of a series of 3-digit industries. Each 3-digit category consists of a series of 4-digit categories. Data is frequently only available only for the 2-digit category. Industries as defined by SIC code groupings do not exactly correspond to the categories defined by the CCST. The closest fit is between software and computer related services and entertainment and the three digit SIC Code, computer programming and data services, 737. For computer and electronics equipment, this study will examine employment in computers and office equipment, 357, in electronic components, 367 and in measurement and control devices, 382. These three industries are classified under three different 2-digit SIC code classifications. For telecommunications, this study uses communications equipment, 366 and communications, 48. Aerospace will include aircraft and parts, 372; guided missiles and spacecraft, 376; and search and navigation equipment, 381. The two digit SIC code category electrical and electronic equipment includes both communications equipment and electronic components and some other industries that might be characterized as technology intensive. Biotechnology and biomedical will be represented by drugs, 283 and research and testing services, 8731. Electronic components and communications equipment are part of a larger SIC code category, electrical and electronic equipment, 36. Because segments of other 3-digit industries in this 2-digit SIC code also might be categorized as science and technology industries, data for the entire 2-digit code is used when measuring the size of the science and technology sector. In a similar vein, search and navigation systems and measurement and control devices belong to the two digit code instruments, 38. Research and testing belongs to the two digit SIC code, engineering and management services, 87. Data for these two digit categories will be reported for similar reasons.

⁴ This estimate probably excludes some biotechnology firms and it excludes engineering services firms that are not classified as research and testing. A more inclusive definition of the science and technology sector yields an estimate of 10 million employed in 1998.

In a few sectors, employment has grown more in the United States than in California. Aircraft and parts is the most notable example. In California, aircraft and parts added 4.1 thousand jobs between 1995 and 1998, a change of 4.9%. In the rest of the United States, aircraft and parts added 68.1 thousand jobs, an 18.6% percentage change. As a result, California's share of total US employment in aircraft and parts declined from 18.7% in 1995 to 16.9% in 1998.

In California, below average growth in aerospace industries (aircraft and parts; search and navigation; missiles and spacecraft) and in communications equipment offset the spectacular growth in computer programming services such that employment growth in the science and technology sector was only slightly above the average for nonfarm industries.

Hence, the science and technology share of total California employment remains about 11%, roughly the same as in 1995.⁵ Nationally, the science and technology sector accounted for 8.3% of total, nonfarm employment in 1998, up from 7.7% in 1995.

The data in Figures 1 and 2 present only a partial picture of labor market conditions for science and technology industries. Employment by industry data is subject to several limitations. One, employment by industry data counts all workers in a particular industry whether the workers are in jobs that require scientific or technological knowledge or not. For example, if a computer software publisher hires a new janitor or secretary, employment in that industry increases. Two, many workers whose jobs are technology intensive work outside of the S&T sector. Employment by industry provides no information about changes in demand for S&T workers in non S&T industries. A third limitation derives from the use Standard Industrial Classification (SIC) system to classify businesses.⁶ The SIC system classifies businesses by their primary activity. Hence, businesses that are engaged in multiple activities -- some in science and technology activities, other not -- might not be classified as science and technology firms. This classification could lead to an undercount of employment in the science and technology sector. On the other hand, for a firm engaged in multiple activities that is grouped in science and technology SIC codes, all of the employment in that firm will be counted as employment in the science

⁵ Science and technology had a 12% share in 1989.

⁶ The US government is switching from the SIC system to the North American Industry Classification System (NAICS) beginning with the 1997 Economic Census. The NAICS system offers structural improvements over the SIC and includes 350 new industries including semiconductor machinery manufacturing, fiber optic cable manufacturing, reproduction of computer software, cellular and wireless communications and satellite communications. The SIC system grouped industries into 10 sectors. The NAICS groups industries into 30 sectors. Most notably, the NAICS defines a new Information sector that includes components from four SIC sectors. Additional information about the new NAICS system is available at <http://www.census.gov/epcd/www/naics.html>.

and technology sector. This classification could lead to an over count of employment. In addition, some SIC codes are so broadly defined that they encompass firms that are science and technology firms and those that aren't. This problem is particularly acute for the measurement of employment in biotechnology and biomedical industries. In its study of the US biotechnology industry, the US Department of Commerce's Office of Technology Policy identified fifteen four-digit SIC that include biotechnology products and services on the market.⁷ (Paugh and LaFrance, 1997) Among the categories listed were vegetables and melons (SIC 0161). To include all of vegetables and melons as a science and technology industry would clearly overstate the size of this sector. To exclude this SIC code and others misses a component of demand for S&T workers.

Supplementing data on employment by industry with data on employment by occupation will address some of these problems. For example, data on the employment of biological scientists may provide more information on the growth of biotechnology than does data on employment in vegetables and melons. Data on the employment of computer programmers will provide information on the demand for these workers by firms both inside and outside the science and technology sector. A list of science and technology occupations was developed using data from the National Employment Matrix.⁸ Table 1 reports the number employed in each occupation by industry (Panel A) and the share of the occupation employed in each industry (Panel B). As inspection of Table 1 reveals, some of the occupations are highly specialized to a particular sector. For example, 59% of aeronautical engineers work either in the private aerospace industry or for the government. Other occupations are distributed more widely. For example, although 34% of computer programmers work in the computer programming and data services industry, another 58% work outside of the science and technology sector.⁹

This occupational data also has significant limitations. Federal agencies group workers according to the Standard Occupational Classification System (SOC) or some

variant of it. The SOC was not updated between 1980 (when it was introduced) and 1998.¹⁰ Yet, the economy has changed rapidly over this period and many new jobs are not reflected in SOC categories. In addition, the occupational categories are very broad. In their study of the information technology labor market, Freeman and Aspray (1999) cite computer programmers as an example. A computer programmer who knows COBOL is not interchangeable with one who knows JAVA. When the IT industry complains of a shortage of JAVA programmers, the available data from the Census Bureau and the Bureau of Labor Statistics can not address the issue.

Figure 3 reports the 1995-1998 change in employment by occupation for the United States using data from the Current Population Survey. The Current Population Survey is a monthly survey of households in the U.S. Figure 4 reports the 1996-1998 change in California employment using data from the Occupational Employment Statistics survey.

The data tell a similar story to the data in Figures 1 and 2. Computer-related occupations experienced the greatest growth between 1996 and 1998.¹¹ Consistent with the below average growth in aerospace, the employment of aeronautical engineers is stagnant.

Employment growth is not uniform across IT occupations. For example, as Figure 5 illustrates, employment of U.S. computer programmers fluctuated down between 1990 and 1994, then increased slowly between 1994 and 1995, and then increased rather dramatically between 1995 and 1997. Some observers have argued that the jump in employment between 1995 and 1997 reflected efforts by the government and other organizations to address the Y2K problem. (Lerman, 1998; Freeman and Aspray, 1999; US Department of Commerce, 1998) As a result of these fluctuations, the growth in US employment of computer programmers averaged only 0.4% between 1990 and 1998. Employment of computer scientists remained robust in the US -- averaging a growth rate of 8.6% between 1990 and 1998.

⁷ The SIC codes for biotechnology products and services on the market were vegetables and melons 0161, animal specialties (not elsewhere classified) 0279, industrial organic chemicals (not elsewhere classified) 2869, pesticides and agricultural chemicals 2879, chemicals and chemical preparations 2899, pharmaceutical preparations 2834, in vitro and in vivo diagnostic substances 2835, biological products (except diagnostic substances) 2836, laboratory analytical instruments 3826, refuse systems 4953, sanitary services (not elsewhere classified) 4959, medical services 8011, clinical medical laboratories 8071, commercial physical and biological research 8731, and testing laboratories 8734. (Paugh and LaFrance, 1997)

⁸ The National Employment Matrix is an on-line, interactive data source at the US Department of Labor, Bureau of Labor Statistics, <http://www.bls.gov>.

⁹ Two percent of computer programmers are employed in the personnel supply industry. These individuals may be working for S&T companies but are not counted as such.

¹⁰ The SOC was revised in 1998. For a discussion of these revisions, see Levine, Salmon and Weinberg, 1999.

¹¹ The occupational categories are not identical in the two data sources. For comparability, the category Computer Scientists and Analysts in Figure Four is a combination of California OES codes 25102 Systems Analysts, EDP; 25103 Data Base Administrators; 25104 Computer Support Specialists; and 25199 All Other Computer Scientists. The category Computer Programmers includes California OES codes 25105 Computer Programmers; 25108 Computer Programmer Aides; and 25111 Programmers, Numerical Control and Process Control.

Table 1. Selected Science and Technology Occupations
Panel A: Number Employed

	Professional Specialties					Technicians		Precision	Production
	Aeronautical Engineers	Electrical Engineers	Computer Engineers	Computer Systems Analysis and Scientists	Biological Scientists	Computer Programmers	Electrical and electronic technicians and technologists	Precision Inspectors, testers and graders	Electrical Assemblers, Precision
Aerospace									
Aircraft & parts	15,362	12,085	1,794	11,263	78	5,903	6,097	19,416	4,114
Guided Missiles & Spacecraft	7,121	4,815	1,990	3,700	*	*	2,299	4,397	3,061
Search & navigation	328	18,809	7,582	2,544	*	1,461	7,318	4,499	*
Computers & Electronics									
Computers & office equipment	*	29,815	15,364	15,692	*	14,027	11,486	14,888	46,047
Electronic components	596	26,704	9,388	6,734	66	4,049	22,133	29,733	42,194
Measurement and control devices	470	10,719	4,686	2,889	299	1,937	9,563	8,685	13,983
Communications									
Communications	119	17,558	2,598	13,138	*	9,258	10,173	7,237	*
Communications Equipment	959	20,910	9,441	4,763	*	2,424	10,117	8,676	16,402
Biotechnology									
Drugs	*	200	*	6,287	11,881	1,205	987	6,974	*
Research & testing services	2,234	20,039	8,378	9,762	12,361	12,180	9,943	11,479	*
Computer Software									
Computer programming and data processing services	181	18,637	76,451	135,947	*	191,866	15,105	4,103	*
Other									
Engineering & Architectural Services	5,385	35,630	12,452	7,951	833	8,693	17,051	4,087	*
Motion Picture Production and Distribution	*	2,169	*	1,251	*	1,146	*	*	*
Personnel Supply	3,584	6,775	3,584	5,333	*	12,198	11,181	31,799	*
Public/Nonprofit									
Government	8,284	34,898	2,506	97,379	31,163	33,756	20,308	19,488	*
Education	139	1,850	139	32,317	10,805	16,137	3,846	570	*
Total Employed	52,514	367,155	215,661	293,905	82,580	568,014	297,428	634,339	194,286

Panel B: Distribution by Industry (In Percent)

	Professional Specialties					Technicians		Precision Production	
	Aeronautical Engineers	Electrical Engineers	Computer Engineers	Computer Systems Analysts and Scientists	Biological Scientists	Computer Programmers	Electrical and electronic technicians and technologists	Precision Inspectors, testers and graders	Electrical Assemblers, Precision
Aerospace									
Aircraft & parts	29%	3%	1%	4%	0%	1%	2%	3%	2%
Guided Missiles & Spacecraft	14%	1%	1%	1%	*	*	1%	1%	2%
Search & navigation	1%	5%	4%	1%	*	0%	2%	1%	*
Computers & Electronics									
Computers & office equipment	*	8%	7%	5%	*	2%	4%	2%	24%
Electronic components	1%	7%	4%	2%	0%	1%	7%	5%	22%
Measurement and control devices	1%	3%	2%	1%	0%	0%	3%	1%	7%
Communications									
Communications	0%	5%	1%	4%	*	2%	3%	1%	*
Communications Equipment	2%	6%	4%	2%	*	0%	3%	1%	8%
Biotechnology									
Drugs	*	0%	*	2%	14%	0%	0%	1%	*
Research & testing services	4%	5%	4%	3%	15%	2%	3%	2%	*
Computer Software									
Computer programming and data processing services	0%	5%	35%	46%	*	34%	5%	1%	*
Other									
Engineering & Architectural Services	10%	10%	6%	3%	1%	2%	6%	1%	*
Motion Picture Production and Distribution	*	1%	*	0%	*	0%	*	*	*
Personnel Supply	7%	2%	2%	2%	*	2%	4%	5%	*
Public/Nonprofit									
Government	16%	10%	1%	33%	38%	6%	7%	3%	*
Education	0%	1%	0%	11%	13%	3%	1%	0%	*
Total Employed	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: United States Department of Labor, Bureau of Labor Statistics, Industry-Occupation Employment Matrix, <http://www.bls.gov>

* No data reported

Nationally, the number of aerospace engineers declined between 1995 and 1998. Most of the job loss occurred in 1992 and 1993. Figure 6 describes this trend. In California, the number of employed aeronautical engineers decreased by 16% between 1996 and 1998.

Because it provides an additional window into the biotechnology and biomedical industry, the employment trend of biological scientists and biological technicians is of special interest. In the United States, as illustrated in Figure 7, the employment of biological scientists grew fairly rapidly between 1990 and 1994, but slowed between 1995 and 1998. In recent years, this occupation appears to be growing more rapidly in California than in the rest of the United States. Between 1996 and 1998, the number employed increased by 36.7% in California, but decreased nationally.

Occupational projections suggest continued growth in science and technology occupations. Figure 8 reports projections of occupational employment in 2006 from the US Bureau of Labor Statistics. Figure 9 reports California projections. Once again, computer related occupations top the charts. Employment of computer scientists is projected to grow by roughly 70% and of computer engineers by roughly 108%. Employment of biological scientists is projected to grow by 35% in California and by 25% nationally. No growth is projected for aeronautical and aerospace engineers in California.

3. Trends in Wages

As described above, employment has been growing in most S&T industries, both nationally and in California. However, an increase in employment could signal either an expansion of demand or an expansion of supply. Distinguishing one scenario from another requires an analysis of wage trends to supplement employment indicators. Employment growth combined with wage growth suggests an increase in demand. Employment growth coupled with falling wages suggests an expansion of supply.

Table 2 describes the trend in annual wage per employee for California's science and technology industries. Annual wage per employee is calculated by dividing the total annual wage by annual average employment.¹² According to this data, wages in computer programming services have grown very rapidly in recent years particularly in comparison to wage growth in total covered employment. This data is consistent with at least one private survey of salaries in the information

technology sector.¹³ Wage growth was also above average in computer and office equipment, in communications equipment and in electronic components.

As an illustration of the folly of relying on wage growth as a sole indicator of demand growth, consider the aerospace industry. Between 1991-1996, missiles and spacecraft experienced above average wage growth despite below average growth in employment. The increase in average wages was probably the result of a change in the distribution of employment within the sector. If low paying manufacturing jobs are moving out, then average wage may increase even as employment falls.

Average weekly wages provide another snapshot of earnings growth. Figure 10 reports the growth in weekly wages for science and technology industries in California. (Unfortunately, this data is not available for Computer Programming Services.) These statistics also show above average growth in most S&T sectors.

The data in Figure 11 paint a slightly different picture of wage growth. Figure 11 reports the annual average growth in median wages for selected science and technology professional and technical specialties. The data are annual averages from the Bureau of Labor Statistics Employment and Earnings.¹⁴ Wages in science and technology occupations tend to be higher than other professions. However, they do not appear to be growing more rapidly than the average wage of all professional specialty occupations. The wage increases in computer-related fields may be part of the general trend of an increased premium for schooling. (Lerman, 1998)

The BLS wage data suggest much lower wage growth than do private surveys of IT workers. (Lerman, 1998; Freeman and Aspray, 1999) Industry data suggests faster wage growth than occupational data. Freeman and Aspray (1999) suggest two possible explanations for these inconsistencies. One is the BLS data does not include non wage compensation such as stock options, signing bonuses and referral bonuses. In addition, the BLS data may not include the incomes of workers who work as independent consultants. A second explanation offered by Freeman and Aspray is a change in the average experience of workers. With rapid growth in an occupation, the average level of experience among workers is likely to fall and this could lead to lower average wages even as the wage, for a fixed level of experience, increases.

¹² This definition of annual wages is given in Holden (1998). The Holden study reports annual wages in California's high tech industries. The data reported here are from unpublished tables provided by California's Economic Development Department.

¹³ Robert Lerman (1998) cites a Coopers and Lybrand study that found average salary increases at 500 software companies were 7.7% in 1995 and 8% in 1996.

¹⁴ Lerman (1998) uses this data to dispute the existence of a shortage of information technology workers.

Table 2. Annual Average Wages in California High Tech Industries

SIC		1991	1992	1993	1994	1995	1996	1997	Wage Growth 1991- 1997	Wage Growth 1991- 1994	Wage Growth 1995- 1997
357	Computer & Office Equipment	\$52,035	\$56,853	\$56,601	\$59,347	\$66,849	\$68,737	\$77,818	49.6%	14.1%	16.4%
366	Communications Equip	\$42,355	\$45,535	\$49,524	\$49,233	\$52,624	\$56,767	\$61,312	44.8%	16.2%	16.5%
367	Electronic Comp	\$37,901	\$41,837	\$43,400	\$45,512	\$49,649	\$51,039	\$56,340	48.7%	20.1%	13.5%
372	Aircraft & Parts	\$42,573	\$45,479	\$46,883	\$49,181	\$50,983	\$52,258	\$56,231	32.1%	15.5%	10.3%
376	Guided Missiles, Spacecraft & parts	\$45,449	\$50,981	\$53,651	\$56,276	\$57,782	\$64,007	\$63,961	40.7%	23.8%	10.7%
38	Instruments	\$42,454	\$45,846	\$47,610	\$49,417	\$52,775	\$54,830	\$58,198	37.1%	16.4%	10.3%
737	Computer Programming & Related	\$43,470	\$48,602	\$51,846	\$55,645	\$58,431	\$64,719	\$68,678	58.0%	28.0%	17.5%
8731	Research & Testing	\$50,775	\$54,444	\$54,420	\$56,273	\$61,054	\$65,096	\$68,737	35.4%	10.8%	12.6%
8733	Noncommercial Research	\$39,098	\$41,120	\$43,733	\$39,769	\$39,685	\$42,620	\$44,726	14.4%	1.7%	12.7%
48	Communications	\$38,929	\$41,074	\$42,770	\$43,907	\$47,784	\$50,013	\$53,028	31.5%	15.0%	8.7%
283	Drugs	\$41,954	\$44,169	\$45,564	\$48,228	\$50,744	\$51,250	\$55,162	31.5%	15.0%	8.7%
	All Industries	\$27,340	\$29,043	\$29,377	\$29,849	\$30,108	\$31,587	\$33,724	23.4%	9.2%	12.0%

Source: *State of California, Economic Development Department Unpublished EOS Data.*

Thus, wage data does not provide an unambiguous picture of demand growth. Although there is above average growth in wages in information technology industries, wage growth in specific IT occupations has not been dramatic. Nevertheless, the absence of a fall in wages eliminates a shift in supply as the sole explanation for employment growth.

4. Defining A Shortage

Economists typically define a shortage as a situation where quantity demanded exceeds the quantity supplied at the prevailing wage. Normally, in a competitive labor market, wages adjust to equilibrate supply and demand. A shortfall in the available quantity supplied of skilled labor should lead to an increase in wages. The increase in wages leads to both a reduction in quantity demanded and an increase in quantity supplied. Or, to depict the theory in more concrete terms, a shortage of skilled labor in the US bids up wages in the US. Higher wages induce workers from other countries to migrate to the US and workers in other occupations to retrain. This worker

mobility leads to an increase in supply. Demand decreases as firms seek production methods that are less skilled labor intensive. The increase in supply coupled with a decrease in demand will return the market to equilibrium. Using this line of reasoning, a labor shortage, if it exists, is a temporary phenomenon.

Economists do recognize that a shortage may persist if there is upward rigidity of wages. For example, with a statutory wage ceiling wages can't respond to an increase in demand. However, there are no legal restrictions on wages in the science and technology labor market other than the minimum wage.

Carolyn Veneri (1999) in the *Monthly Labor Review* identifies two other definitions of a shortage used by economists. One definition of shortage is a situation where the supply of persons with specific skills is less than the quantity socially desired. Society might demand that the ratio of first graders to teachers be 20 to 1. Under this definition, any higher ratio would mean a shortage of teachers.

A second definition applies the term "shortage" to a period of transition from one equilibrium to the next. In a 1959 article in the *Quarterly Journal of Economics*, Kenneth Arrow and William Capron use the term dynamic shortage to describe the engineer-scientist market in the 1950s. The opening of Arrow and Capron's article could just have easily been written to describe the current debate over IT workers.

"The frequent and loud complaints of a shortage of engineers and scientists heard over the past eight years or so might be taken as indicating a failure of the pricing mechanism and indeed have frequently been joined with (rather vaguely stated) proposals for interference with market determination of numbers and allocation. It is our contention that these views stem from a misunderstanding of economic theory as well as from an exaggeration of the empirical evidence. On the contrary, a proper view of the workings of the market mechanism, recognizing in particular, the dynamics of market adjustment to changed conditions, would show that the phenomenon of observed shortage in some degree is exactly what would be predicted by classical theory in the face of rising demands." (Arrow and Capron, 1959, p. 298)

A dynamic shortage occurs when demand increases more rapidly than supply. If prices or wages take time to respond to an increase in demand, the quantity demanded at a point in time will exceed the quantity supplied at that point in time. The shortage is temporary, but if demand continues to increase, the market could experience a sequence of these "temporary" shortages.

Arrow and Capron (1959) argue that wages may not adjust instantaneously because of information lags. It takes time for the employer to recognize that he will not be able to fill vacancies at the going wage rate and to respond by increasing salaries. It takes time for workers to realize that higher salaries are available and then to respond. As long as demand continues to increase more rapidly than supply, there will be chronic shortages and wages will spiral upwards. Other factors that might slow market adjustment include the dominance of government or nonprofits as employers, the cost and time required for job training, and the ease of migration.

Veneri (1999) suggests three indicators of a dynamic shortage: a) higher than average employment growth; b) higher than average wage growth; and c) historically low unemployment rates. In addition, it is important to assess the responsiveness of supply to changes in demand.

5. Is Supply Responding to Increased Demand?

Many studies have pointed to the decrease in the number of graduates with science and engineering degrees

as evidence that supply is not responding to the growth in demand. Nationally, the number of bachelors degrees awarded in math, computer science and electrical engineering¹⁵ decreased between 1990 and 1996. However, the number of master's degrees and doctorate degrees awarded has increased.¹⁶ Figure 12 shows the number of degrees awarded in electrical engineering from 1966 to 1996. The number of bachelor's degrees awarded in electrical engineering began its decline in the mid 1980s. Although the number of bachelors degrees continued this decline through the 1990s, the rate of decline has slowed. There has been little change in the number of bachelor's degrees awarded in electrical engineering since 1993.

A similar pattern characterizes computer science degrees. As Figure 13 illustrates, the number of bachelor's degrees awarded increased dramatically between 1975 and 1985-1986 and then nearly as dramatically decreased. Although the number of degrees awarded continued to decline through 1996, the rate of decline slowed. In both computer science and in electrical engineering, the number of master's degrees increased.

Figure 14 focuses on an occupation where employment has declined -- aeronautical and aerospace engineering. It reports the number of degrees awarded in aeronautical engineering. The number of bachelor's degrees in this area have decreased since 1991 -- much more rapidly than in electrical engineering. However, this decrease is a fairly recent phenomenon. Because a BA degree takes four years, we might expect a delayed reaction to changes in demand.

The number of BA degrees awarded in biological and life sciences has increased. Figure 15 shows the trend in degrees awarded in this field. Here the pattern is opposite that observed for engineering, math and the physical sciences. The number of degrees awarded decreased from the late seventies through 1990 and since has increased.

Figure 16 reports the number of degrees awarded by California's public colleges and universities. The time series is shorter than that available for the United States as a whole, but it reveals a similar pattern of decline since 1990. Only the number of degrees awarded in life sciences has increased.

Despite the alarms sounded by the AEA, the ITAA and others, very little research has been devoted to

¹⁵ This finding depends on the definition of science and engineering. NSF statistics report an increase in degrees awarded, but their definition includes economics, sociology and psychology.

¹⁶ A common practice is to report the total number of degrees awarded (bachelors, masters and doctorates). This convention will not be used here for two reasons. One, for purposes of calculating cumulative supply, this practice might lead to double counting of some degree recipients. Two, the master's degree contains different information since it might be used as avenue for retraining by persons whose undergraduate degrees are not in a computer related field.

understanding why the number of majors in math, computer science and engineering have declined. The US Department of Commerce study *America's New Deficit* offers four possible explanations for the decline in the number of computer science degrees. First on the list is a lack of proficiency in mathematics. Despite recent improvements, in 1994, only 59% of high school graduates had completed a second course in algebra or a course in chemistry. Only 24% had completed a course in physics. Yet, this preparation is essential for students planning college majors in math, science or engineering. Second on the list is a lack of information about job opportunities: "defense industry cutbacks and corporate downsizing have left many students with the impression that there are fewer job opportunities in the computer field." (*San Jose Mercury News*, May 24, 1997, as cited by the US Department of Commerce) A study of Silicon Valley high school students (AT Kearney Report, 1999) found low awareness of high tech careers relative to other careers. Less than 20% of the surveyed students perceived Math, Physics, Chemistry or Electronics as relevant to high tech careers. A third problem is that many students do not believe universities provide the proper training and are seeking other types of training -- "on the job training is increasingly substituting for formal four year university education in computer science." (*Washington Post*, October 11, 1996, as cited by US Department of Commerce)

One indicator of a worker shortage is the difference between the number of graduates and the number of new jobs in a field. Figure 17 reports the gap between math, computer science and electrical engineering degrees and total employment in computers and electronics and computer software. There was a new worker surplus (i.e., number of graduates greater than number of new jobs) as recently as 1994. The cumulative deficit between 1994 and 1996 was 129,266 jobs.

How are these jobs filled? Essentially, there are two methods -- one, migration of workers from other countries and two, career switching by persons with degrees in other areas.

Between 1994 and 1997, the United States admitted 52,342 immigrants with mathematical and computer scientist or engineer listed as occupation. California was a popular destination for all immigrants, including those with professional specialties. Of legal employment based immigrants to California in 1996, 18.2% were engineers and mathematical and computer scientists. (State of California, Department of Finance, 1996) The H-1B visa program, although controversial, has probably had only a modest effect on the supply of workers. The program has an upper limit of 65,000 workers of all types per year. (This limit will temporarily be raised to 115,000 in 1999 and 2000.) This program is open to workers in many fields. There are no official statistics on how many persons in each field are admitted, but some estimates suggest that no more than 20,000-25,000 of the

H-1B visa recipients are information technology professionals. (Freeman and Aspray, 1999) California also attracts skilled workers from other states. Roughly half of the respondents to Allen Scott's survey of multimedia and visual effects workers received their highest level of education outside of the region. (Scott, 1998)

In computer related fields, career switching is prevalent. Nearly half of employed math and computer scientists have degrees in non-science fields. (See Figure 18) The Freeman and Aspray study identifies ten academic disciplines other than computing disciplines that offer strong training for information technology (IT) careers. (Freeman and Aspray, 1999) Some are obvious -- mathematics, engineering, and physics. Others -- philosophy and music for example -- are more of a surprise. According to the report, music graduates "have learned about the manipulation of pattern themes within constraints" and philosophy majors have strong logical thinking ability and may have taken courses in mathematical logic. Both preparations serve as a good background for programming. As Figure 19 illustrates, a growing number of students in non-computer disciplines have earned semester credits in computer science.

The ease of attracting workers from other fields varies by sector and by job. Two factors are important in determining the rate of career switching: (1) the availability of individuals with the academic preparation to learn a new skill and (2) the availability of training. Workers with academic backgrounds in non-science disciplines (and those with backgrounds in science, but who lack the required preparation for the available jobs) have multiple options to acquire new skills. First, there are formal degree programs. The increase in the number of master's degrees awarded in math and computer science may reflect retraining efforts of persons with academic backgrounds in other fields.

A second option is a non-degree program offered by a formal educational institution -- including vocational training schools such as DeVry or ITT Technical Institute. In the American Electronics Association's report *CyberEducation*, ITT Technical Institute is the top school by high tech degrees in California. A third option is a training program offered by a private educator or by a product supplier. Distance learning and electronic learning technologies offer a fourth option.¹⁷ Although firm provided training is unusual for workers trying to enter a field, the high tech industry does appear to be a leader in retraining workers. The high technology sector spends roughly \$911 per employee on training compared to average of \$499 per employee for all organizations. (ASTD, 1998)

¹⁷ Bassi, Cheney and Van Buren provide a overview of the trends in electronic learning technologies. (Bassi, Cheney and Van Buren, 1997)

Thus, for some IT jobs, there is an available pool of trainable labor. The important question then becomes how long a training period is required. After a review of the available evidence, Freeman and Aspray study conclude, "It does not take all that long for someone with good academic skills to retrain for many IT occupations.

The length of these training programs varies. For example, about six months of full time training can prepare an individual with some scientific programming experience to become an entry-level Unix systems administrator. A two year associate's degree program can enable a high school graduate to work as a computer programmer or a computer maintenance technician." Other jobs clearly require more extensive training.

6. Is There A Shortage?

Returning to the question of whether there is a labor shortage in the science and technology sector, there is evidence on both sides of the question. Beginning with Veneri's three indicators, employment growth is above average in some science and technology sectors, but the evidence on wages is mixed. Some California S&T industries have both above average employment growth and wage growth. Others have above average wage growth, but below average employment growth, suggesting either a restructuring of employment or a change in skill requirements. Unemployment rates in science and technology occupations are low. Figure 20 reports unemployment rates for selected high tech occupations. The unemployment rates in high tech occupations were generally two percentage points below the population average. The National Science Foundation reports low unemployment rates for most science and engineering graduates.

Another indicator of a worker shortage is the vacancy rate. Unfortunately, there are no official sources of data vacancy rates, but there are private surveys that offer evidence of high numbers of unfilled jobs. (ITAA) The General Accounting Office in its review of America's Deficit cautions against over reliance on the private surveys given the poor response rates. (GAO) Nevertheless, the robustness the finding of high vacancy rates across surveys leads some credibility to this result. (Lerman also cautions that vacancy rate data, even if reliable, may not be a good indicator of labor shortages.) Employer surveys suggest it is difficult to find qualified IT professionals. (Holden; Silicon Valley Joint Venture; ITAA)

On the supply side, Barr and Tessler argue that foreign labor pools for IT workers are tapped out. The number of math and science degrees awarded are decreasing, but, as Lerman and others have noted, IT professionals don't necessarily have degrees in math and science. Others point to untapped pools of labor -- such as older

programmers and engineers as evidence the labor shortage may be exaggerated. Finally, the increased demand for programmers may be episodic.

In summary, the signals are mixed as to whether there is a labor shortage (as economists would define it). The market does appear to work. Indicators of supply responsiveness include the growth in the number of master's degrees in science and engineering awarded and the slow down in the rate of decline in the number of bachelor's degrees awarded. The market works. It just works slowly and this slow adjustment to equilibrium is not without costs. For the state of California, those costs might include less science and technology employment in California.

7. Is California Losing Ground in Science and Technology?

The market appears to work, but will the new market equilibrium mean less high tech jobs in California? The answer depends on whether California's labor costs remain competitive with other states and labor costs will depend on California's ability to supply skilled labor. California can maintain its competitive edge in two ways -- one, by continuing to attract skilled labor from other states and other countries and two, by developing a pool of skilled labor among current residents. California continues to attract skilled labor from other states and from abroad. However, it is slipping behind other states in providing the academic preparation for its current population of school age children.

Table 3 describes California's share of total US employment in science and technology industries. Third column reports an index created by dividing the first column by the second. This index measures California's share of total US science and technology employment as a proportion of its share of total employment. When this number equals one, California's share of total US science and technology equals its share of total employment. An index of greater than one indicates that California enjoys a larger share of S&T than it does of total employment.

California continues to enjoy a greater share of science and technology employment than of all employment; however, the index is getting smaller. One contributing factor is the decline in aerospace employment in California. As Figure 21 illustrates, California lost aerospace jobs both because of an overall decline in that sector and because some jobs shifted to Washington State.¹⁸ In contrast, California has increased its share of

¹⁸ The A. T. Kearney report *Beyond Consolidation...* offers the aerospace industry's perspective on this job loss in aerospace. The report identifies lower costs -- better wage rates, state and local taxes, cost of living -- as a major factor in relocation decisions. (A. T. Kearney, 1998).

Table 3. Index of California's Share of US Science and Technology Employment

	<i>Column A</i>	<i>Column B</i>	<i>Column C</i>
Year	CA Employment/ US Employment, Science and Technology	CA Employment/ US Employment, All Industries	Ratio of Columns A& B
1989	0.17	0.11	1.50
1990	0.17	0.11	1.48
1991	0.17	0.11	1.48
1992	0.17	0.11	1.48
1993	0.16	0.11	1.45
1994	0.15	0.11	1.44
1995	0.15	0.11	1.43
1996	0.15	0.11	1.43
1997	0.15	0.11	1.41
1998	0.15	0.11	1.40

Source: State of California, Economic Development Department, Unpublished OES Table, Cali0AA8.xls, United States Department of Labor, Bureau of Labor Statistics, Selective Data Access, <http://www.bls.gov> and Author's Calculations.

jobs in the drug industry, primarily at the expense of New Jersey.

Nevertheless, the loss of jobs in some sectors and the lack of growth in others provide grounds for concern.

California is also losing ground in its share of US production of science and technology degrees. Figure 22 depicts the number of bachelor's degrees awarded in science and technology in California as a ratio of the total number awarded in the United States. Again, the change is not dramatic, but California's share is getting smaller.

Some of the erosion of both job share and graduate share may be linked to a lack of math proficiency among K-12 students in California. The lack of math proficiency means that there are fewer students prepared to enter training and certificate programs for jobs as electronic technicians; and fewer students prepared to major in math, science and engineering fields in college.

Among the fifty states, California ranks 32nd in eighth grade math scores and 37th in science scores out of 40 states for which data was available. California ranks 50th in students per computer and 43rd in percentage of schools with internet access. In 1997, California averaged 12.5 students per computer in schools. The national average was 7 students per computer. (AEA *CYBEREDUCATION*) Calfee's survey of high tech employers in California underscored the importance of K-12 education. (Calfee, 1999) A majority of respondents perceived a general lack of preparedness of students graduating from secondary schools with respect to science and technology positions.

8. What Are Implications for Public Policy?

To remain competitive, California must either increase the number of scientists, engineers, and other skilled workers that it attracts from other states and abroad or it must increase its own production of these workers.

Admittedly, there is some appeal of the first strategy. Let other states and countries invest in high quality primary and secondary education then reap the benefits of this investment by luring these workers to California. However, there are also disadvantages. In addition to the environmental and congestion costs associated with population growth, a strategy of importing skilled workers, with low investment in the current school age population, will lead to greater economic and social inequality.

On the other hand, there are also costs associated with attempting to increase the "home grown" supply of science and technology workers. Freeman and Aspray (1999) offer the cautionary tale of the federal government's efforts to increase the number of scientists and engineers in the late 1980s. In response to projected shortfalls of scientists and engineers, Congress increased funding for the National Science Foundation's education programs and many educational institutions increased the numbers of graduate students in science and engineering fields. Unfortunately, when this larger cohort reached the labor market, demand had deteriorated and the graduates were left unemployed and frustrated.

This cautionary tale illustrates one of the major pitfalls of government intervention in an otherwise functioning market -- things change. Indeed, a rapidly changing technology usually means a rapidly changing set of skill requirements for workers. Because things change, career

paths in growth areas like information technology and biotech tend to be nonlinear. (Freeman and Aspray, 1999; Scott, 1998) In the traditional linear career path, a prospective worker begins training through formal education then gets a job in his field of concentration and works his way through the ranks. In the non-linear model, workers move between education and work throughout their careers. To succeed in this new model, workers need strong basic skills and opportunities for lifelong learning.

This analysis suggests two avenues for increasing the "home grown" supply of science and technology workers - strengthen basic skills through improvements in K-12 education and expand opportunities for lifelong learning. Both strategies are fairly low risk because they prepare workers to respond to changes in demand. Both have the added benefit of increasing the attractiveness of California as a destination for skilled workers.

In addition, there may also be a need to increase awareness of career opportunities in science and technology industries. A survey of high school students in Silicon Valley found low awareness of careers in high-tech and a lack of interest in math and science. (A.T., Kearney, 1999) Less than 20% of the surveyed students recognized that math, physics, chemistry or electronics were relevant to high-tech careers. There may also be a need for outreach programs to increase interest in these fields for African Americans, Latinos and white women. All three groups continue to be underrepresented in science and technology fields of study. (National Science Foundation, 1998)

9. Summary of Labor Market Conditions

Given the range of industries included in the science and technology sector and the diversity of skill requirements, it is useful to conclude with a summary of labor market conditions in the five industries targeted by the CCST project.

Aerospace. Nationally, employment of aerospace workers has increased in recent years and is projected to enjoy modest growth into the next century. However, employment is shrinking in California thanks in part to consolidation within the industry and to the relocation of manufacturing facilities. Despite the decline in employment, average wages of aircraft industry workers in California have been increasing. The number of degrees awarded in aeronautical engineering has decreased.

Biomedical and Biotechnology. The data on this industry is sketchy but the available evidence suggests that employment in this sector is growing and it is growing in California relative to the rest of the country. The number of degrees awarded in biological and life sciences is also increasing. Wages are growing but not at a faster than average pace.

Computer and Electronics. There has been a modest increase in employment since 1995 both in California (slightly above the average for all nonfarm employment) and in the U.S (below the average for all nonfarm employment). Wage growth has also been modest. The number of degrees awarded in electrical engineering and in computer engineering has decreased.

Software and Computer Related Services. This industry has been an engine of growth for the science and technology sector. Employment has increased both nationally and in California. In the computer programming and data services industry wage growth is substantially above the average for all industries. However, wages in specific computer related occupations do not appear to be growing rapidly. The number of degrees awarded in computer science is decreasing, but many math and computer scientists majored in other fields.

Communications. This industry is also difficult to characterize adequately with existing data. Employment growth has been below average in communications equipment, but above average in communications services. However, only five percent of employment in communications services can be considered high-tech. Wage growth is near the average for all industries.

Overall, demand is growing and labor markets are tight. There may not technically be a shortage of science and technology workers, but there is upward pressure on wages. Furthermore, there is the prospect that with higher wages some jobs will leave the state. To avoid losing its position as a leader in science and technology, California must address the educational shortcomings that constrain the supply of labor in these industries.

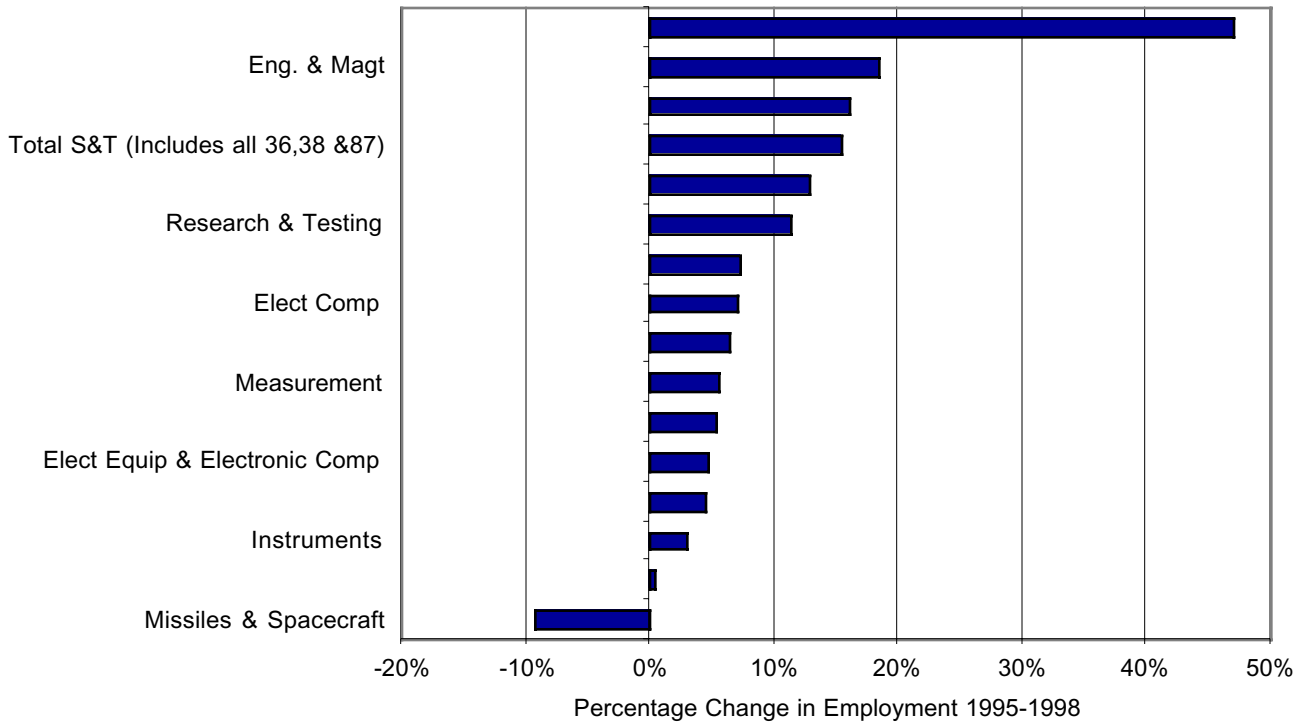


Figure 1. Nationally, Computer Programming Experienced Greatest Employment Growth
 Source: United States Department of Labor, Bureau of Labor Statistics, Series Reports, <http://www.bls.gov>

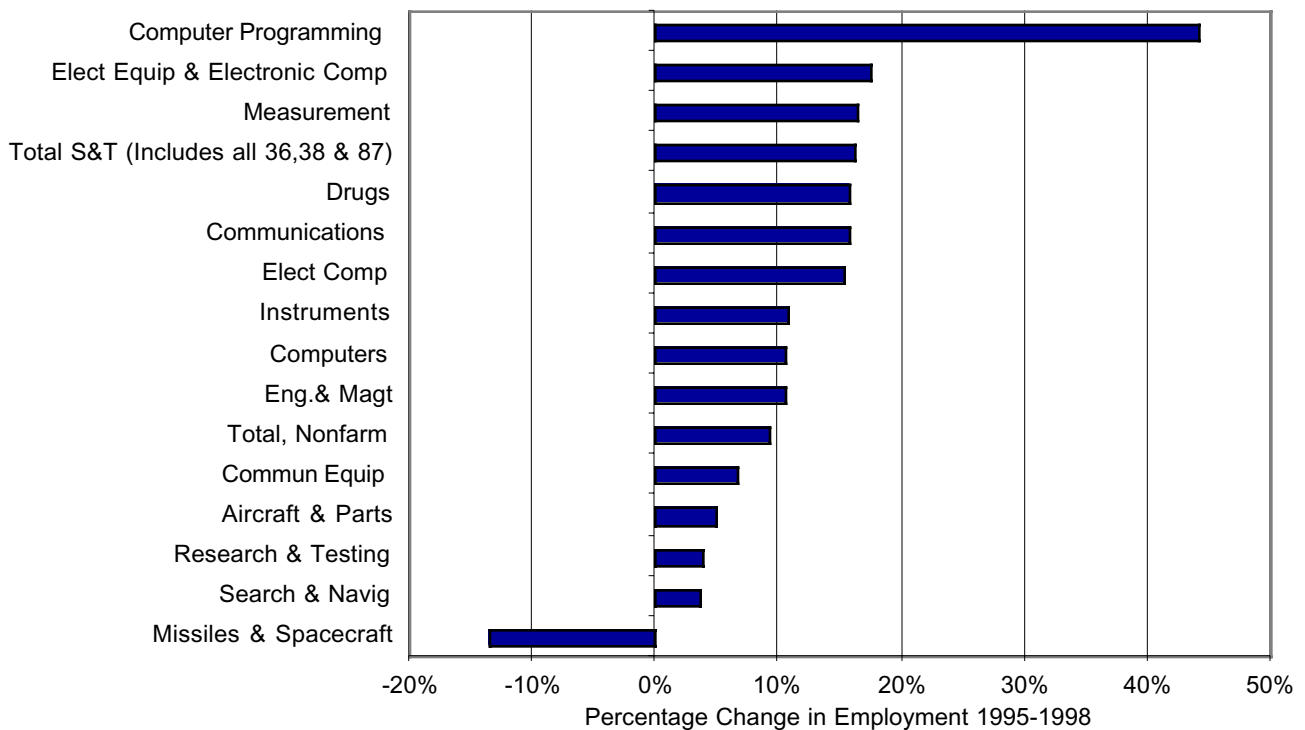


Figure 2. Employment Growth in Computer Programming Services Also Outstrips Other Sectors in California
 Source: US Dept of Labor, Bureau of Labor Statistics, State and Area Employment, Hours and Earnings

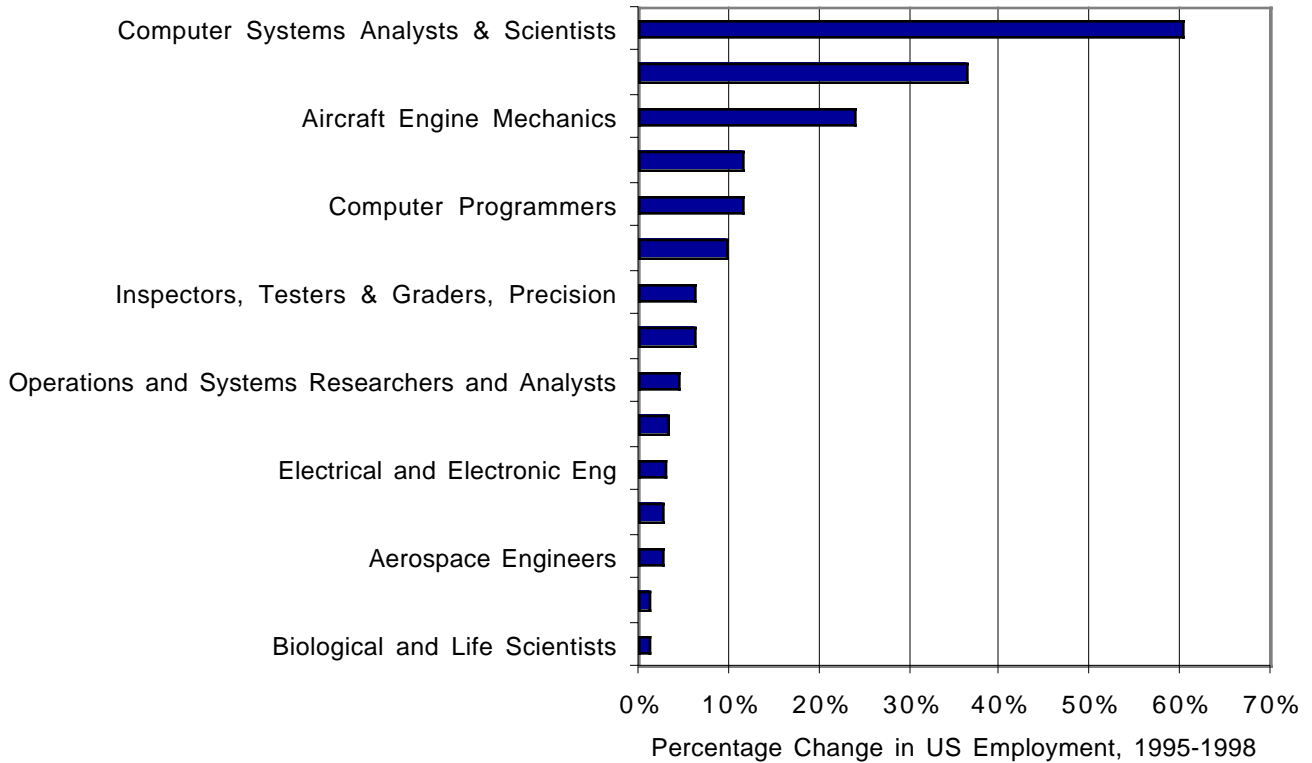


Figure 3. US Employment Change, 1995-1998

Source: United States Department of Labor, Employment and Earnings, Annual Household Averages

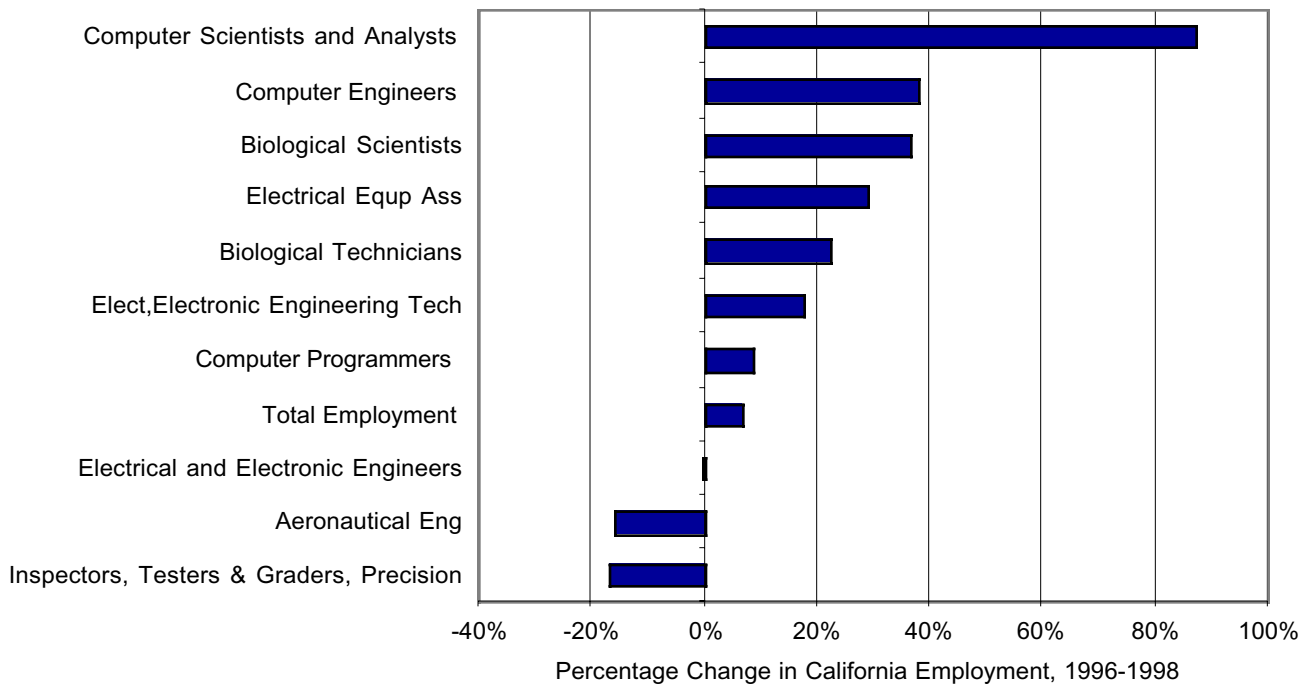


Figure 4. California Employment Change, 1996-1998

Source: <http://www.calmis.cahwnet.gov>

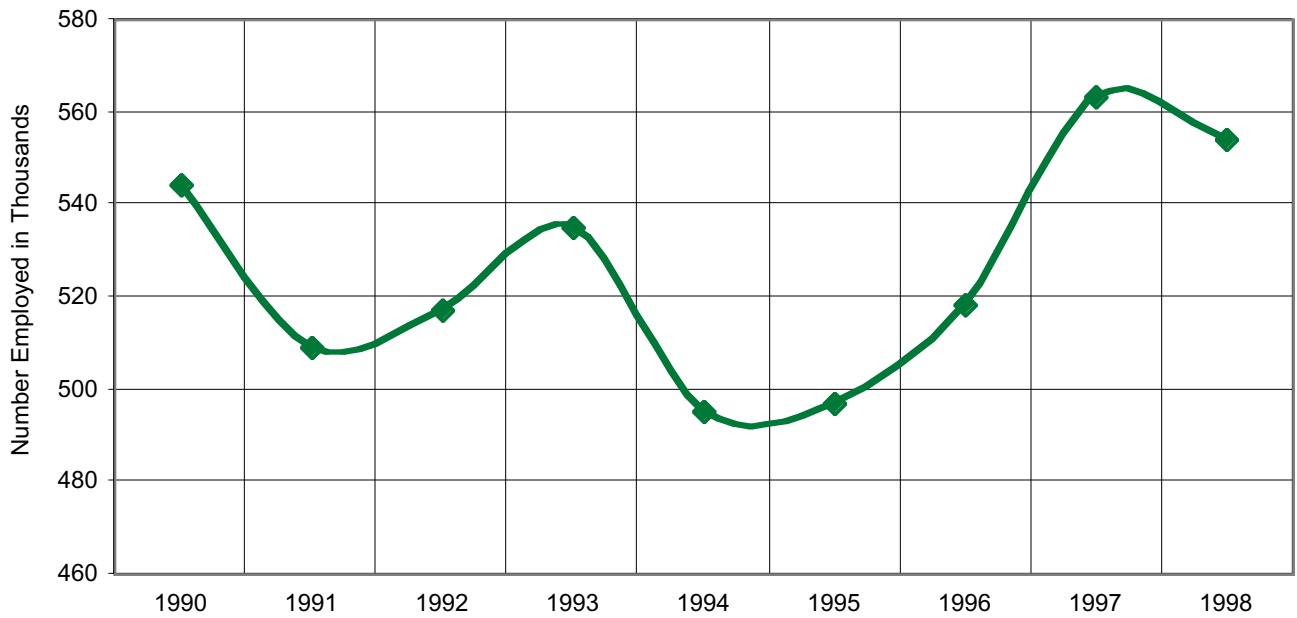


Figure 5. Employment of Computer Programmers Has Fluctuated

Source: United States Department of Labor, Employment and Earnings, Annual Household Averages

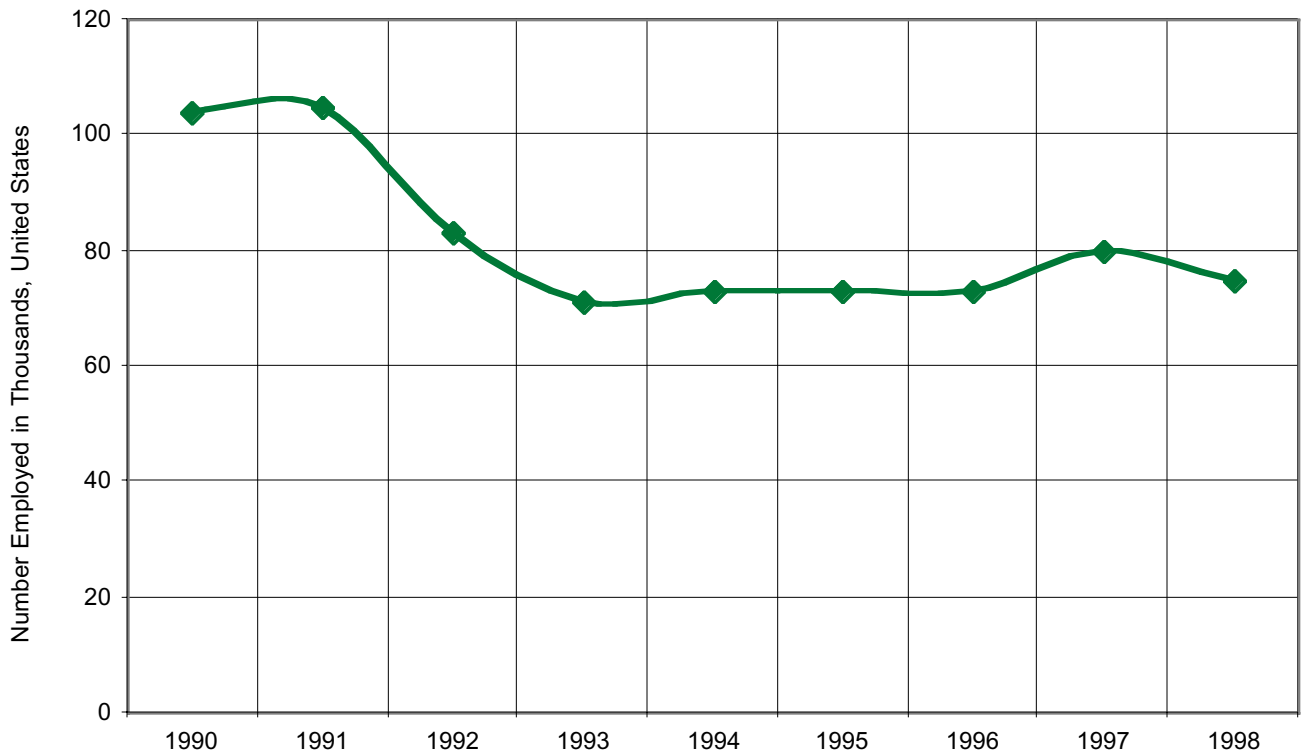


Figure 6. Dramatic Decline in Aerospace Engineers 1991-1994

Source: United States Department of Labor, Employment and Earnings, Annual Household Averages

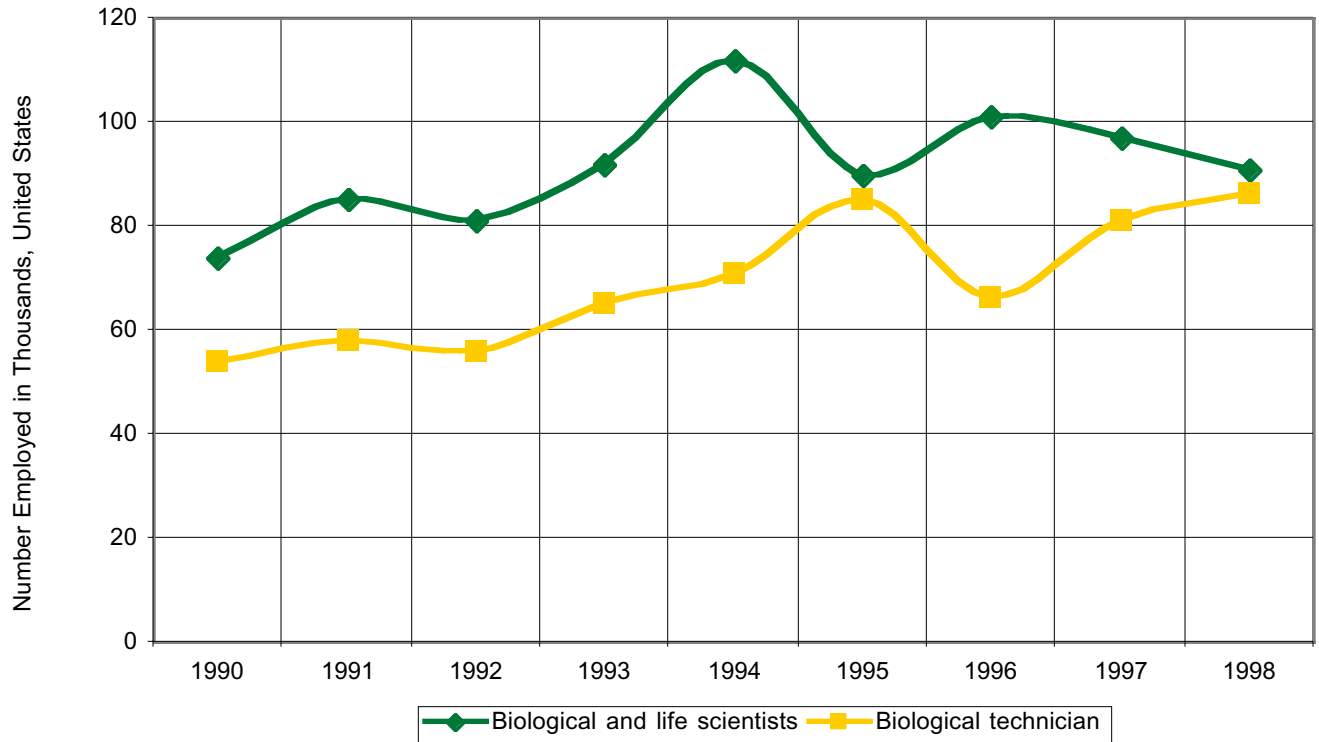


Figure 7. Biotech Occupations Grew Between 1990 and 1994, But Slowed Recently
 Source: United States Department of Labor, Employment and Earnings, Annual Household Averages

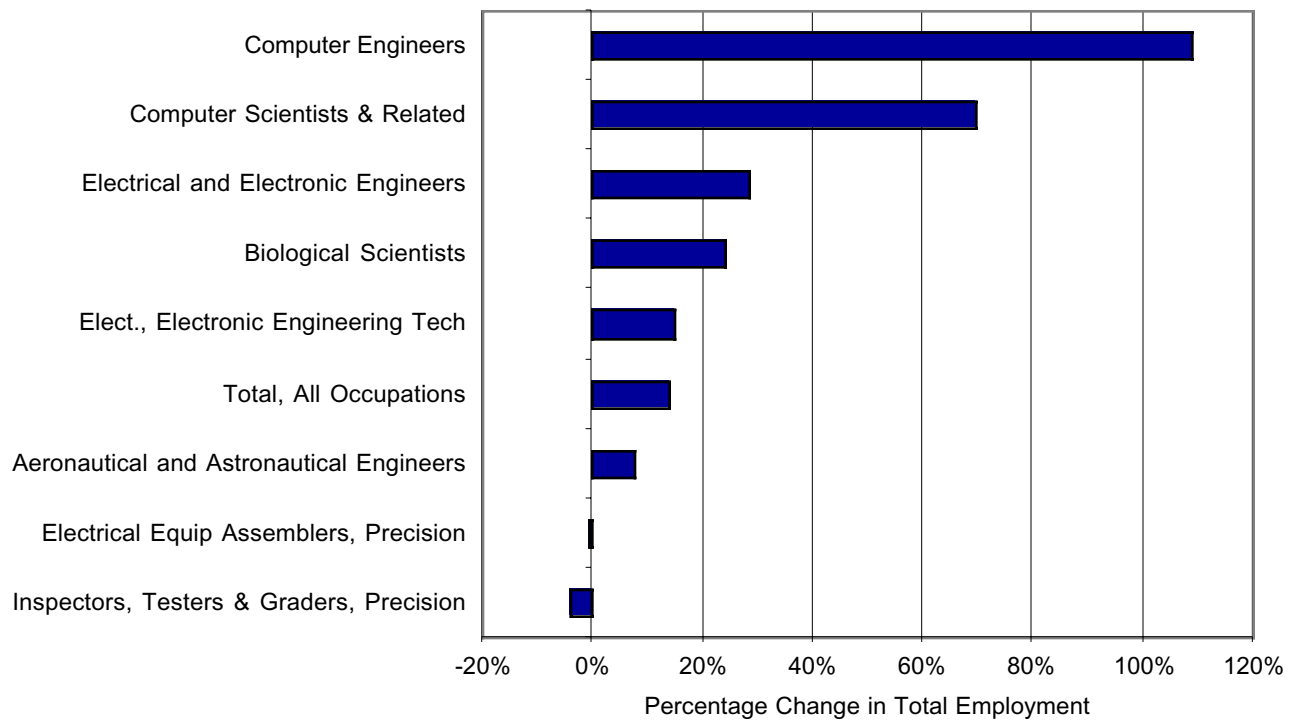


Figure 8. Projected Change in US Employment, 1996-2006
 Source: United States Department of Labor, Employment Projections, <http://www.bls.gov>

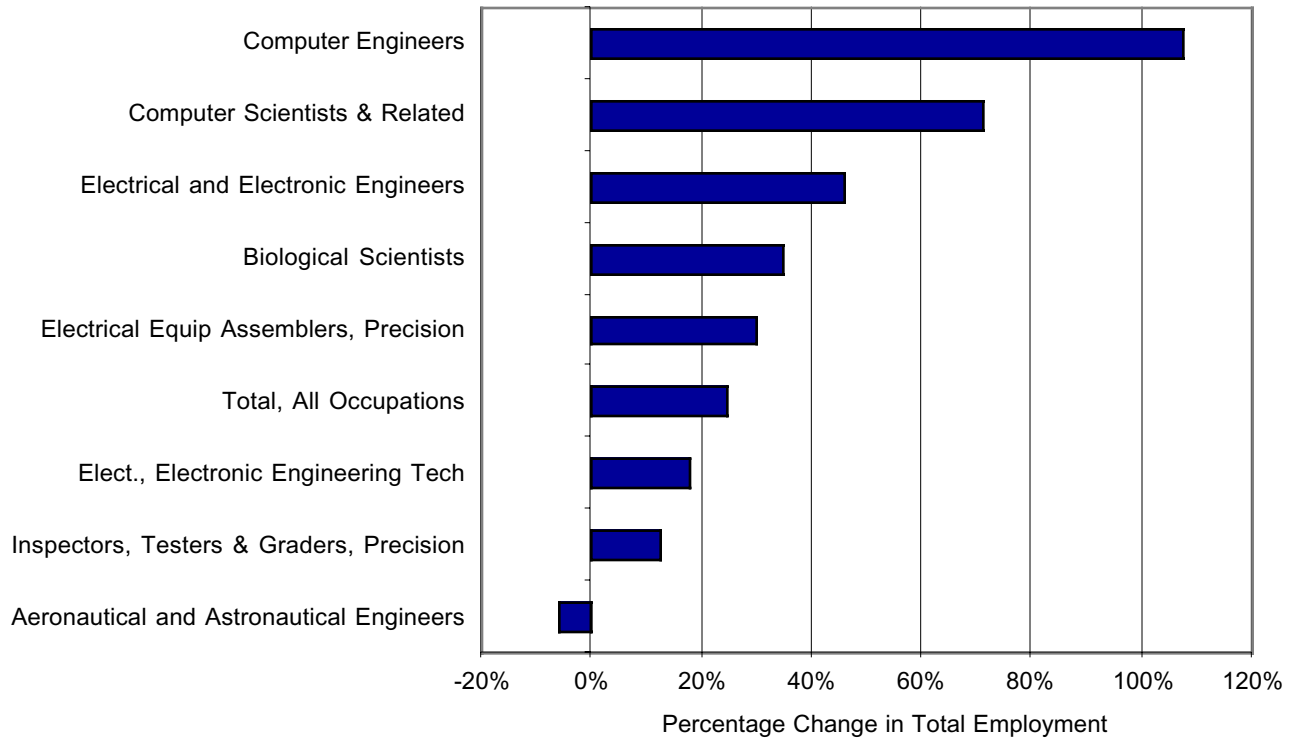


Figure 9. Projected Change in California Employment, 1996-2006
 Source: State of California, Employment Development Department, <http://www.calmis.cahwnet.gov>

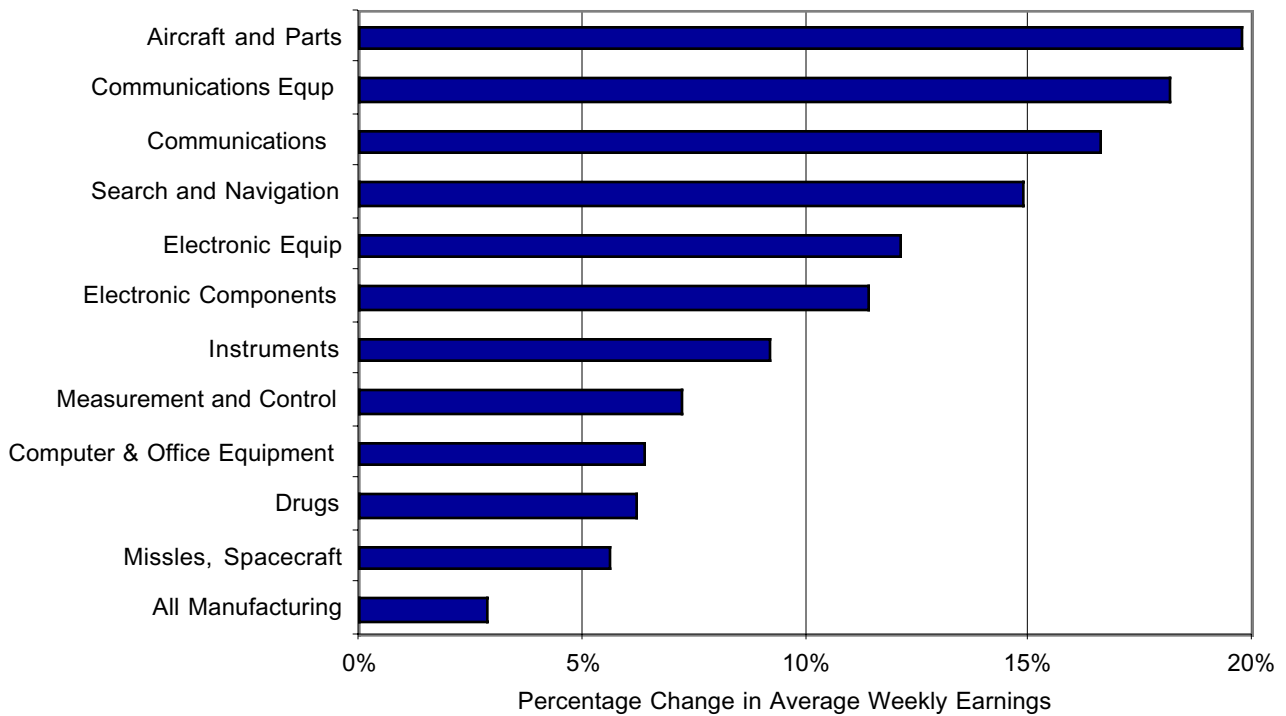


Figure 10. Change in Average Weekly Earnings, California 1995-1998
 Source: State of California, Employment Development Department, Unpublished tables

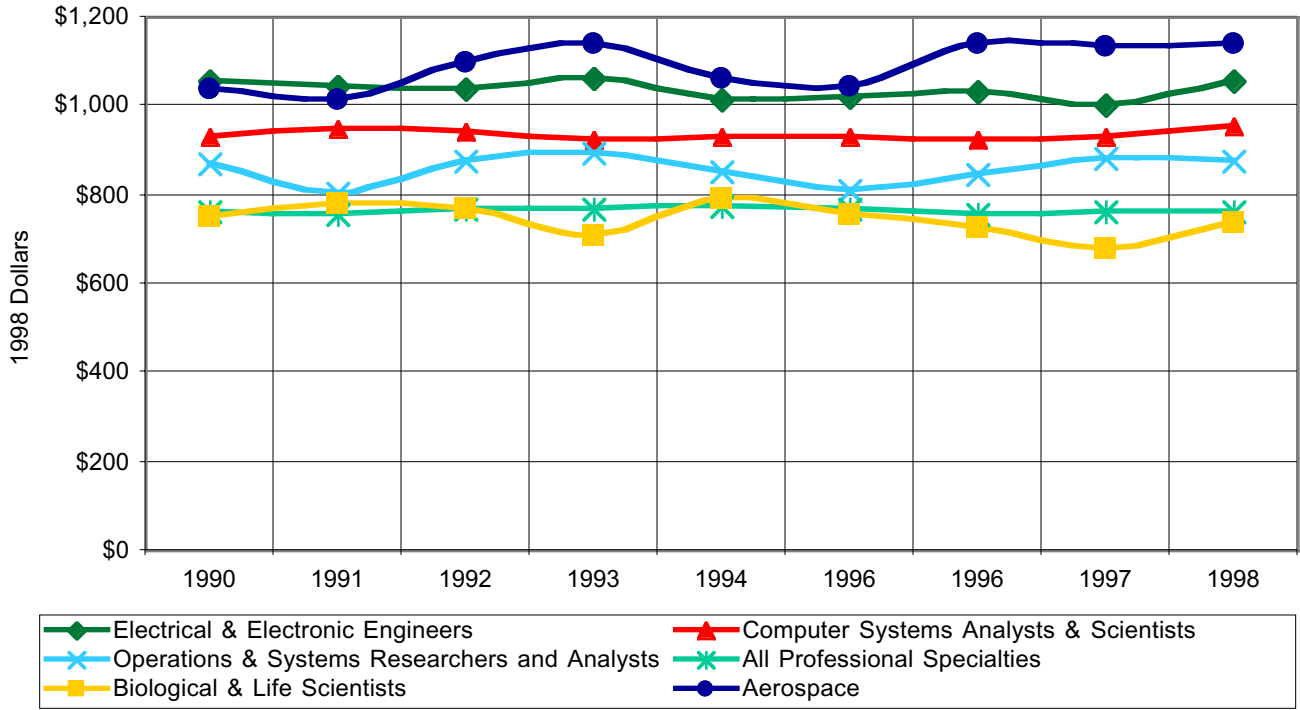


Figure 11. Median Weekly Wages (1998 dollars)

Source: United States Department of Labor, Employment and Earnings, Annual Household Averages

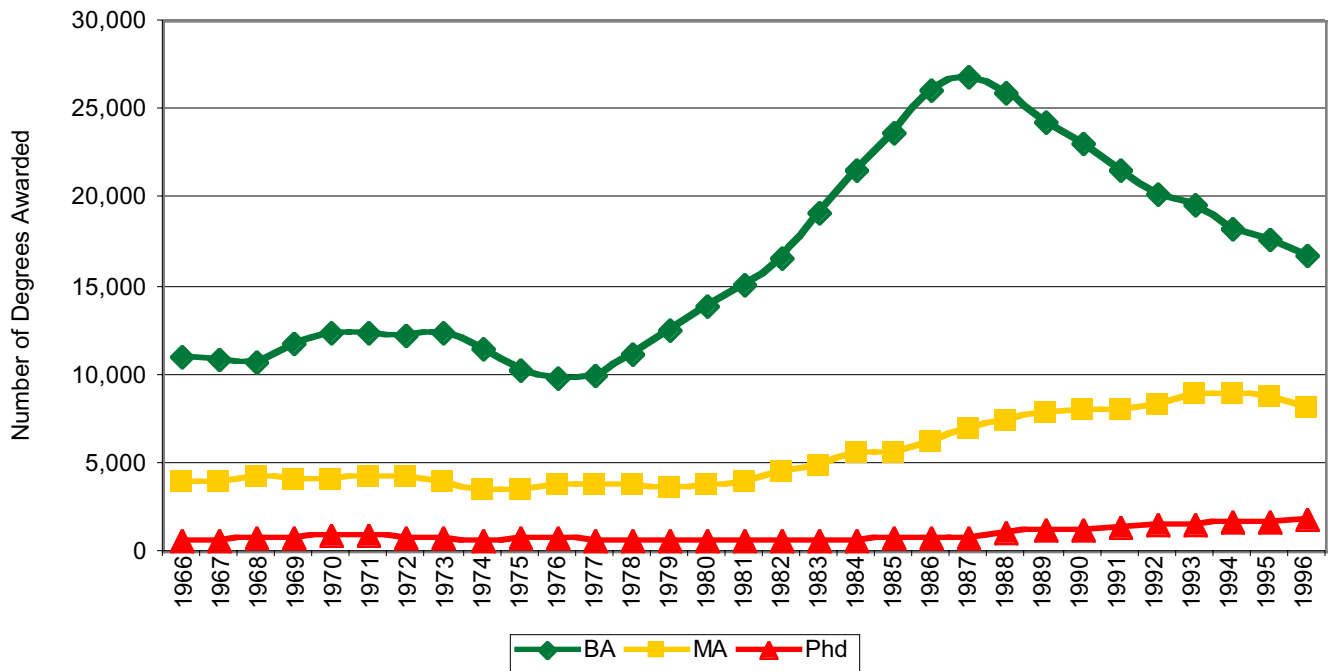


Figure 12. Electrical Engineering Degrees Awarded in the United States, 1966-1996

Source: National Science Foundation, Science and Engineering Degrees 1966-1996, <http://www.nsf.gov>

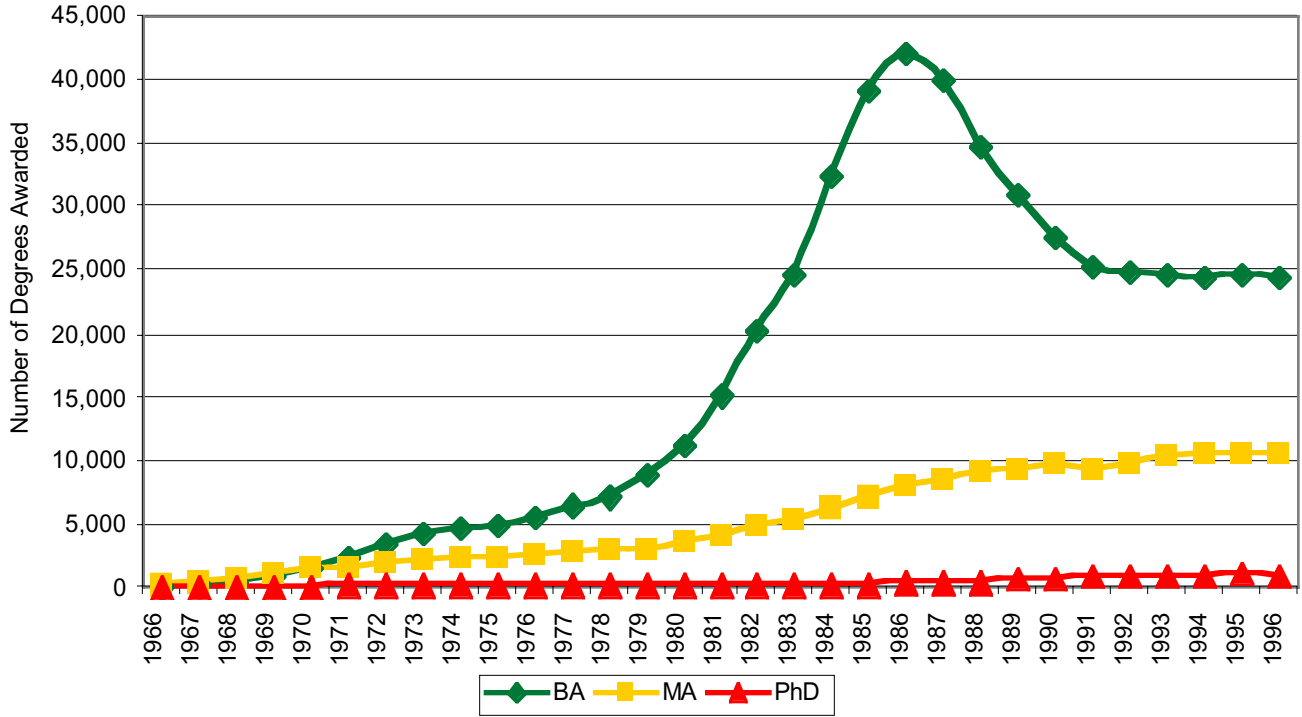


Figure 13. Computer Science Degrees Awarded in the United States, 1966-1996

Source: National Science Foundation, *Science and Engineering Degrees 1966-1996*, <http://www.nsf.gov>

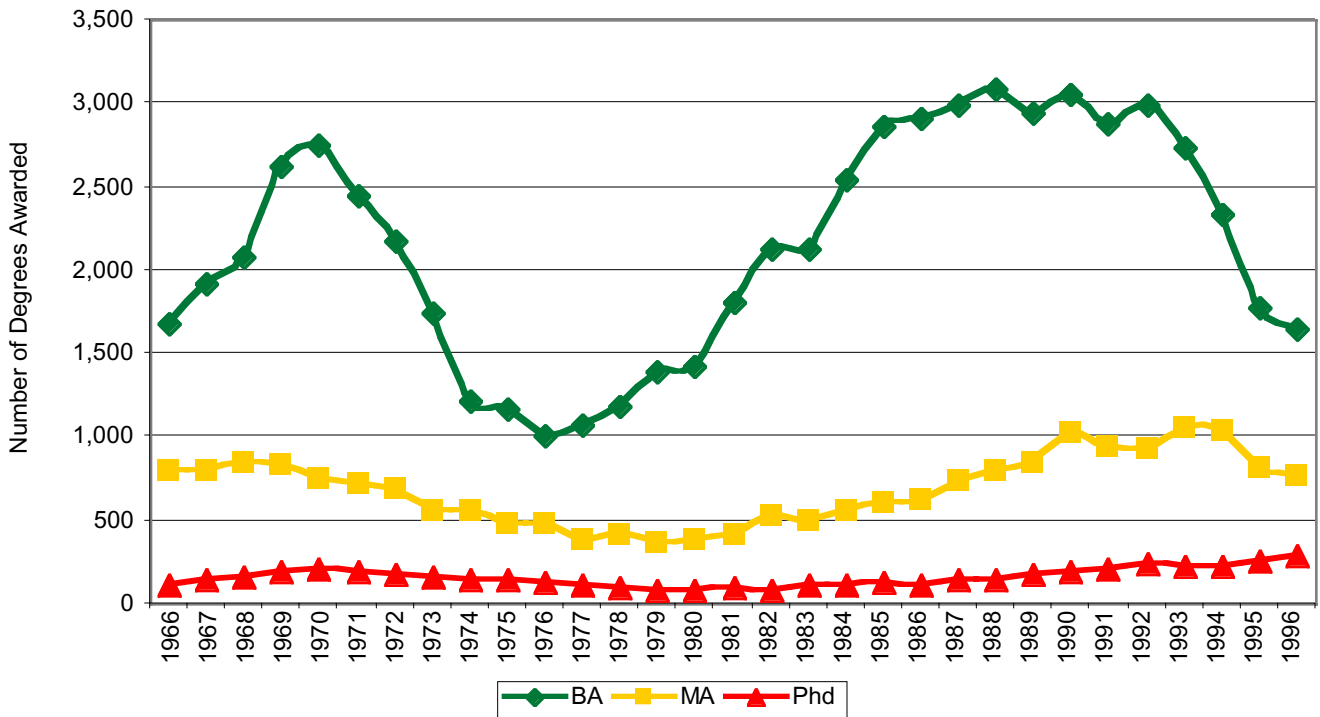


Figure 14. Aeronautical Engineering Degrees Awarded in the United States, 1966-1996

Source: National Science Foundation, *Science and Engineering Degrees 1966-1996*, <http://www.nsf.gov>

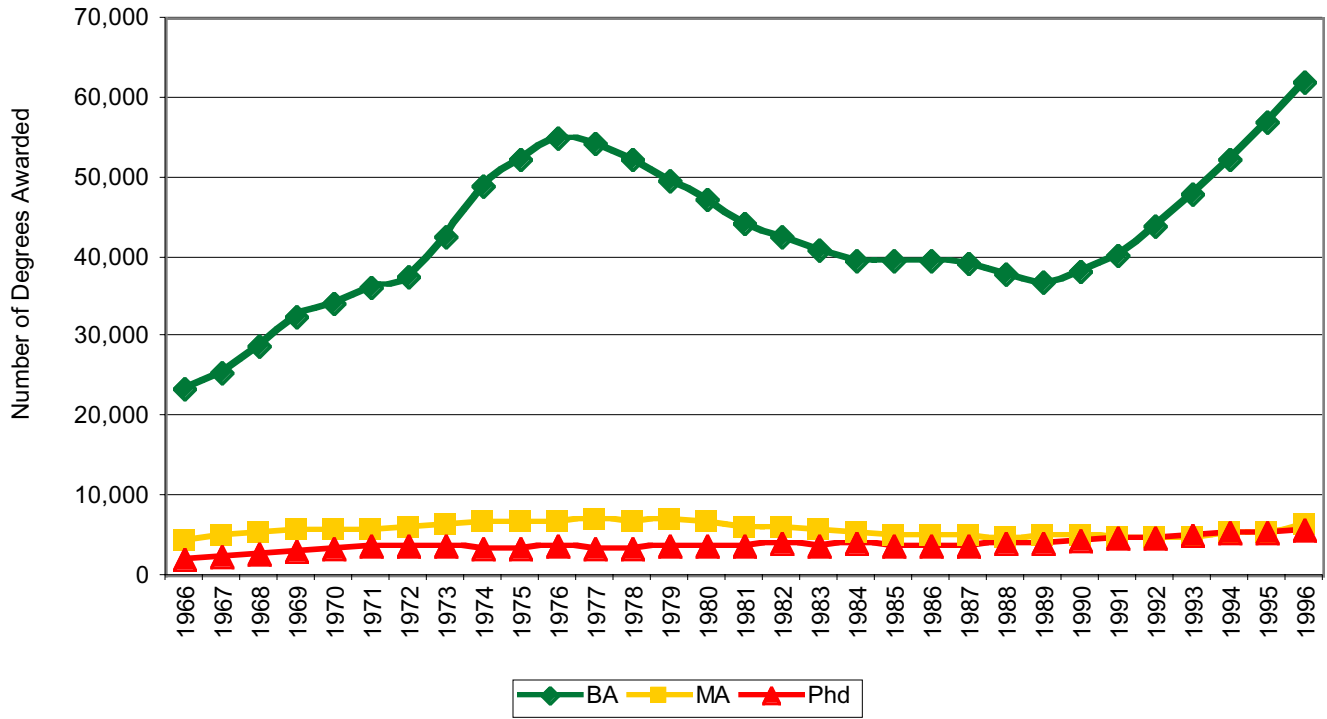


Figure 15. Degrees Awarded in Biological Sciences, United States
 Source: National Science Foundation, *Science and Engineering Degrees 1966-1996*,
<http://www.nsf.gov>

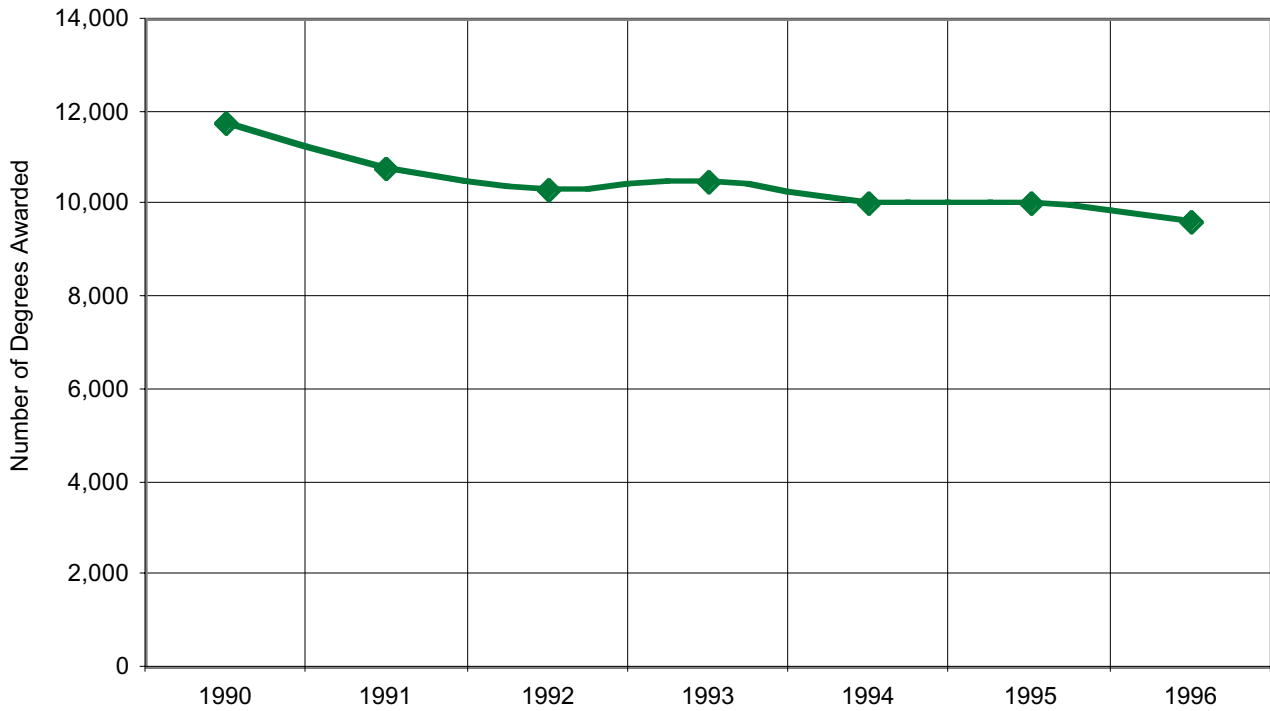


Figure 16. Science and Engineering Degrees Awarded in California
 Source: American Electronics Association, 1999. *CyberEducation*

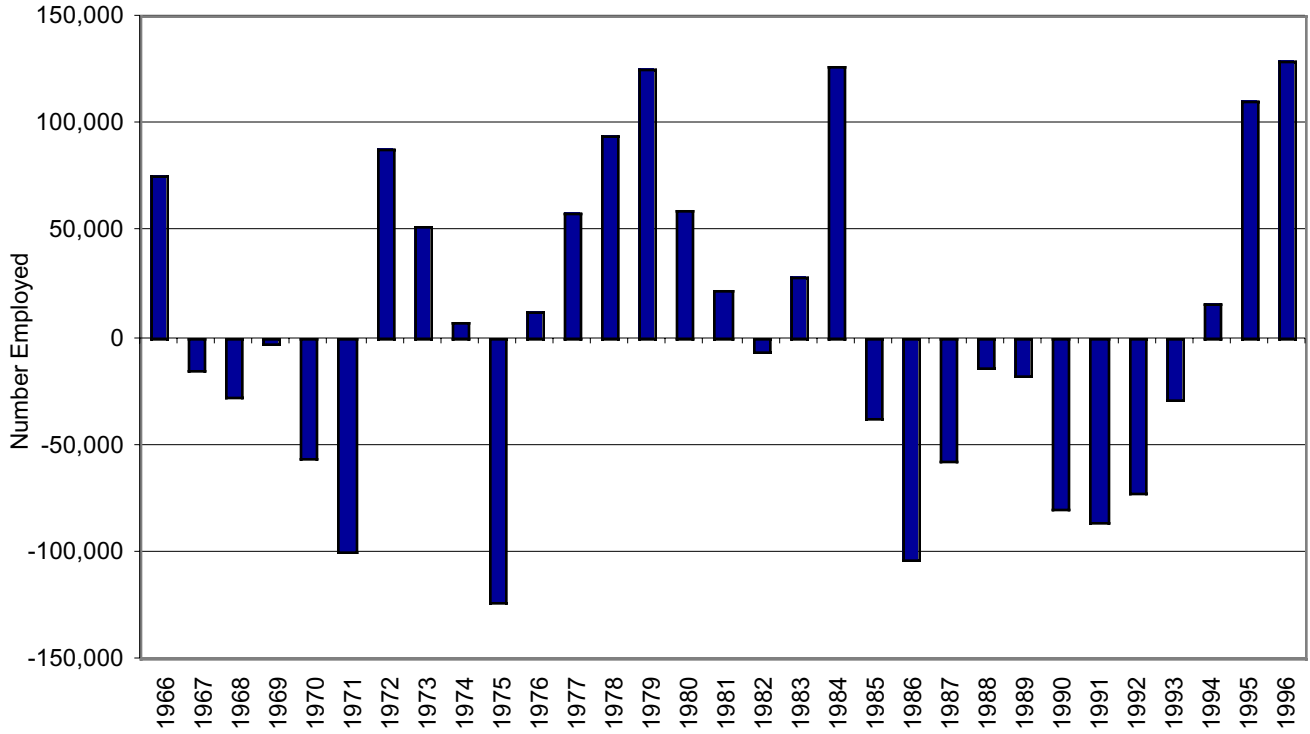


Figure 17. Job Deficits in Math, Computer Science and Electrical Engineering
 Source: Author's calculations

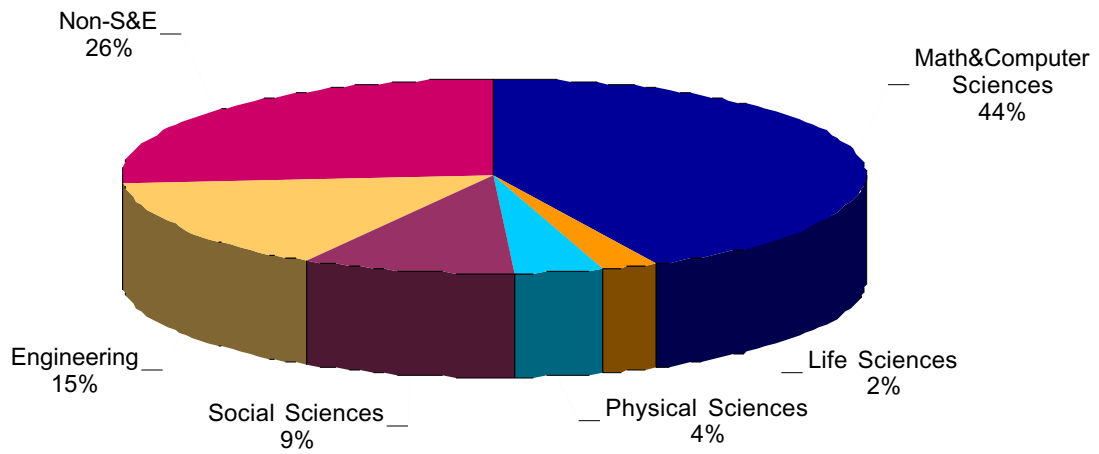


Figure 18. Percentage of Employed Computer and Math Scientists by Degree Field
 Source: National Science Foundation, Science and Engineering Indicators-1998.

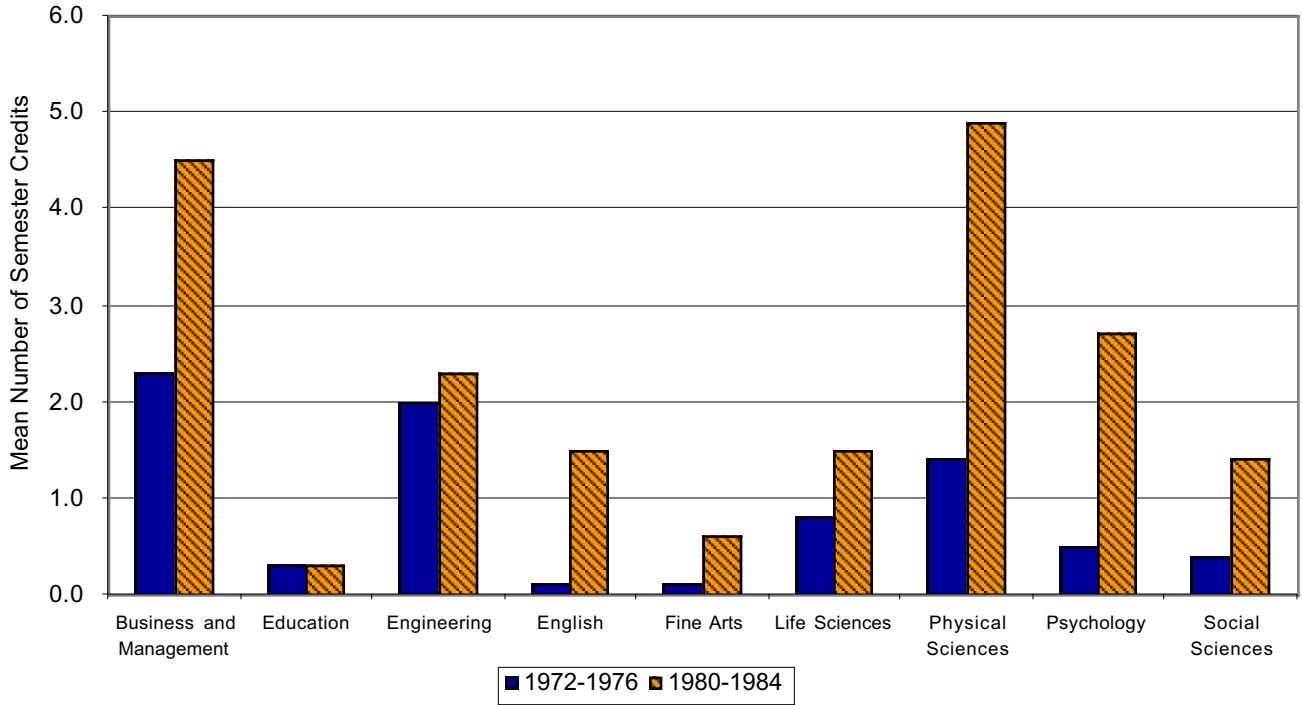


Figure 19. Semester Credits in Computer Science Completed by Bachelor's Degree Recipients
 Source: United States Department of Education, National Center for Education Statistics, <http://nces.ed.gov>

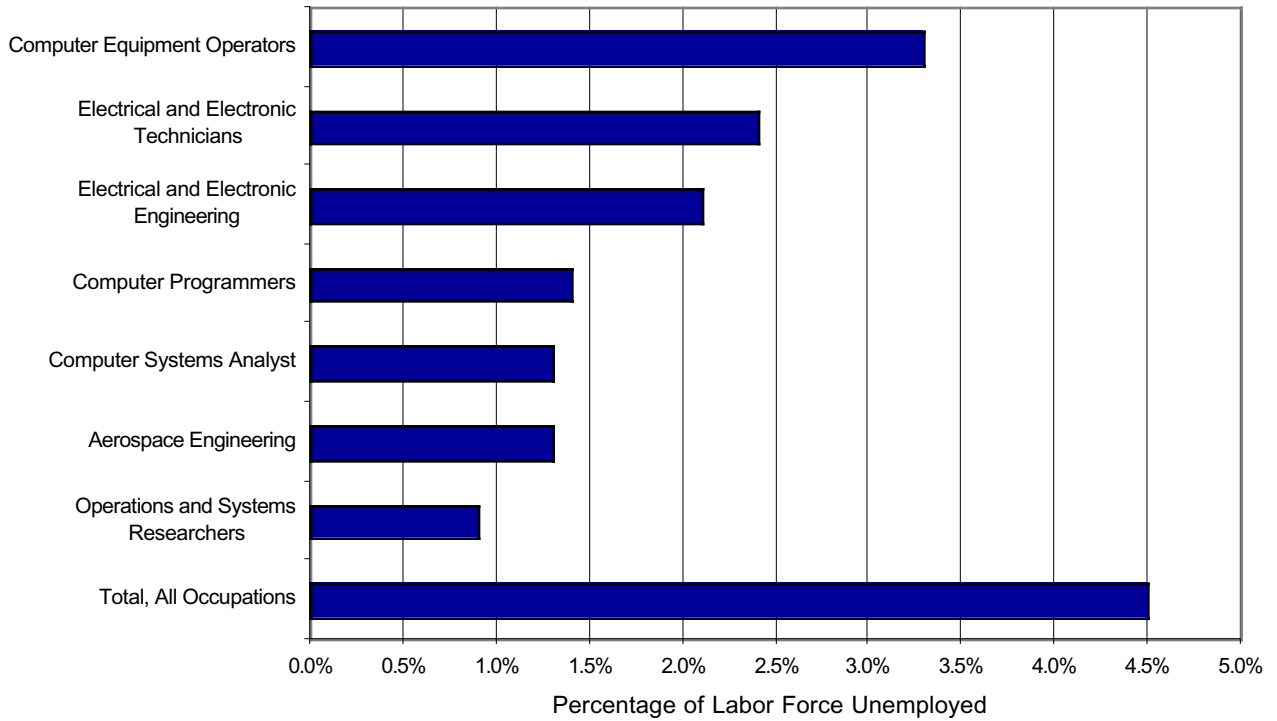


Figure 20. 1998 Unemployment Rates, Selected Occupations
 Source: American Electronics Association, CYBEREDUCATION

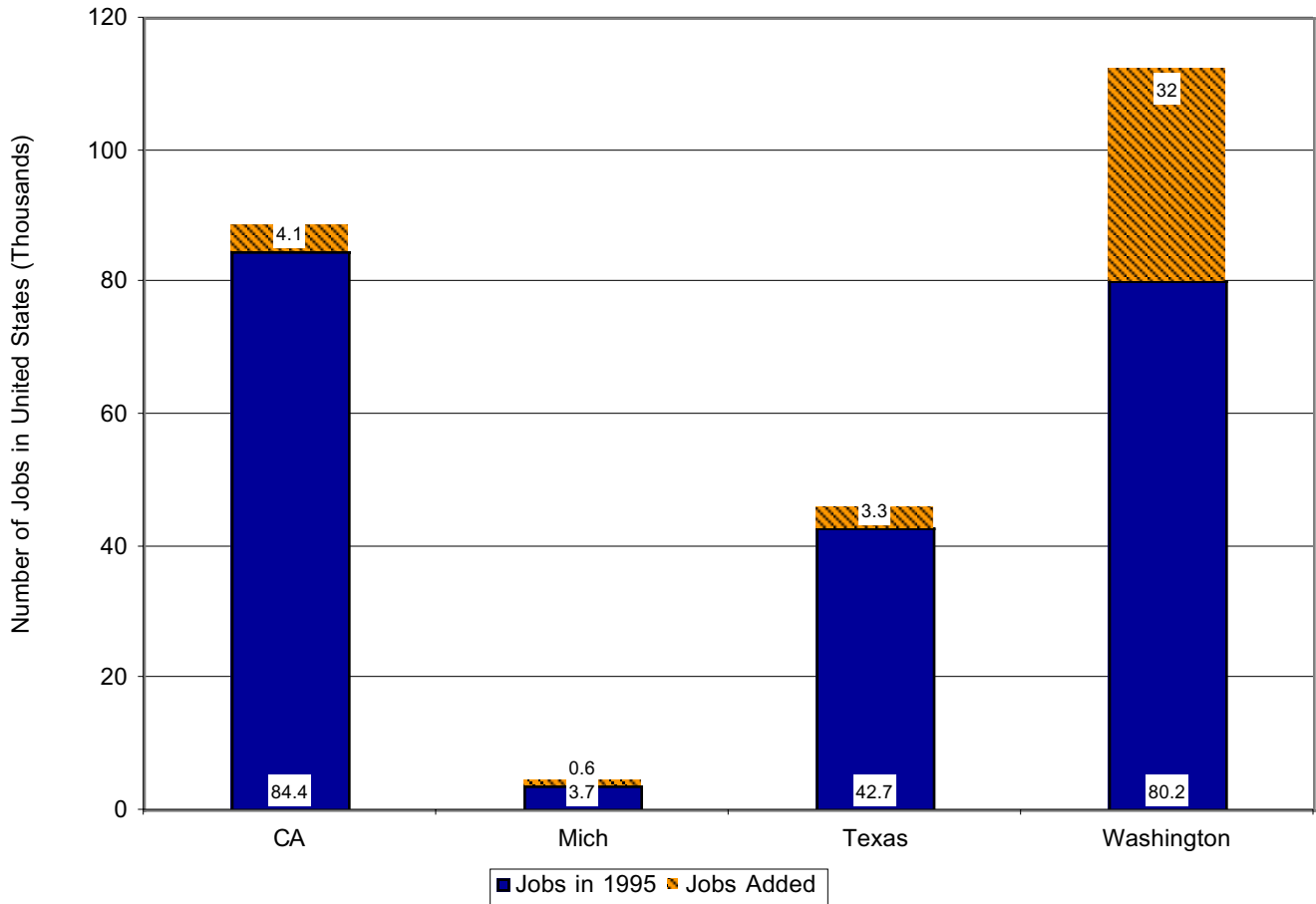


Figure 21. Job Growth and Total Employment in Aircraft and Parts, 1998

Source: United States Department of Labor, Bureau of Labor Statistics, State and Area Employment Statistics
<http://www.bls.gov>

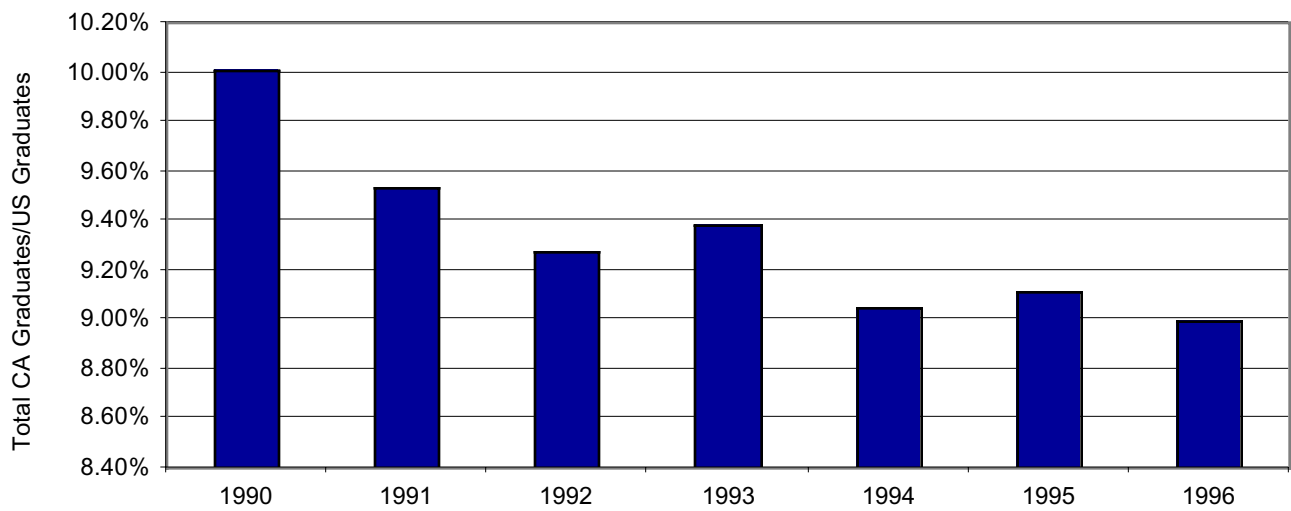


Figure 22. California's Share of the Production of US Science and Technology Graduates Has Fallen

Source: American Electronics Association, CyberEducation

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