# ARIZONA'S TECHNOLOGY WORKFORCE: ISSUES, OPPORTUNITIES AND COMPETITIVE PRESSURES*

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# Executive Summary

This report summarizes the findings of a research project that analyzed the labor market for scientists and engineers (S&E workers) in Arizona.[1] A cornerstone of the project was the collection and analysis of primary data obtained in surveys and interviews with high-technology companies operating in the state. The surveys and interviews were designed to solicit information on the recruiting practices and hiring experiences of local technology companies, from the companies themselves. The focus of the questions was on the nature of any difficulties companies may have had when recruiting scientists and engineers to work in Arizona.

Because of the mobility of technology workers, state and regional labor markets for scientists and engineers are highly integrated. This means that the manpower issues faced by companies in Arizona are likely to be very similar to those faced by other technology firms throughout the country. With this in mind, the report begins with a review of important trends and issues in the national market for scientists and engineers.

In addition to a presentation of the primary data obtained from company surveys and interviews, the report provides an analysis of secondary data available from government sources. Data on the earnings of S&E workers in Arizona are examined to test whether shortages of science and engineering workers have been more acute in Arizona than in the rest of the country. The report also presents information on the flow of new science and engineering graduates from colleges and universities in Arizona and other states. These data are reviewed with an eye towards determining whether Arizona technology companies might be handicapped in their recruiting of S&E workers by a low rate of production of new graduates in the state.

What follows is a brief summary of each major chapter in the report.

## The National Market for Scientists and Engineers

Notable among recent developments in U.S. science and engineering employment have been changes in the demographic makeup of workers. Increases in employment of female and foreign-born S&E workers have offset a sharp decline in the number of native-born male workers. Foreign-born workers have become critical to the highly educated S&E workforce. More than half of all architects and engineers with a Ph.D. are foreign born. Roughly one-half of U.S. workers in computer and mathematical occupations who have a Ph.D. are foreign born.

The rise in the foreign-born share of U.S. scientists and engineers over the past two decades has been made possible by a liberalization of U.S. immigration laws targeting highly educated skilled workers. Particularly important has been the creation of the H-1B temporary worker visa.

Inflation-adjusted wages in science and engineering occupations fell on average during the 1990s. Since 2000, wage increases in S&E occupations have been faster than the rate of inflation and above or near the average of all occupations in the economy. However, S&E wages have risen at a considerably slower pace than wages earned by people in management positions and by health care practitioners. Among S&E workers, architects and engineers have experienced the fastest wage

[1] S&E refers to Science & Engineering, a broad category of technology-related employees that includes computer scientists, engineers, and scientists. Throughout the report the terms "scientists and engineers," "S&E workers," and "technology workers" are used interchangeably.

growth. But wage growth of a similar magnitude has also been recorded in other skilled occupations, including law and business and financial operations.

Ever since the Soviet launch of Sputnik in the 1950s, recurring claims have been made by the scientific community and executives of high-tech companies of shortages of S&E workers. To economists, labor shortages are self-correcting and temporary. If at going wages businesses want to hire more scientists and engineers than are currently available then competition between employers will force wages up, and this will serve to address the shortage. The statistical evidence reviewed shows that U.S. wages and salaries of scientists and engineers have lagged behind those in other occupations requiring a high level of training and education. If rapidly rising pay is the primary indicator of a labor shortage, then the country faces more acute shortages of business executives and managers, doctors and pharmacists, lawyers and financiers.

Instead of talking about general labor shortages, it would be more accurate to say that the U.S. has an adequate supply of scientists and engineers but only because of a sizeable influx of foreign-born students and technical workers. The U.S. is not experiencing a shortage of scientists and engineers but of native-born entrants into these fields. The question is whether anything should be done about it. For young Americans to choose careers in science and engineering rather than medicine, law or finance, wages in S&E occupations must rise significantly. But if they do, many of these jobs will go overseas.

The most important factor shaping future trends in the U.S. market for S&E workers is a rapid increase in science and engineering capabilities in other countries of the world. Global developments – especially trends toward mass higher education in highly populated developing countries – are eroding U.S. dominance of science and technology. The policy area that is most critical in determining the path of U.S. adjustment to these trends is immigration. Is it better to recruit more foreign students and technical workers from the world's labor pool, or force U.S. multinationals to compete by offshoring an increasing amount of high-tech production and research? Immigration preferences for foreign-born students would play to the strong competitive advantage the U.S. enjoys in graduate-level education. Knowledge spillovers also favor immigration over offshoring. Productivity in the domestic workforce is better served by allowing the local population to work with highly educated foreign workers instead of just buying goods from them.

## The Mobility of S&E Workers: Does Local Training Create a Larger Workforce?

Americans are some of the most geographically mobile people in the world. Educated Americans are especially mobile. In view of the mobility of highly educated U.S. workers, it is fair to raise the question of whether states should worry about the rate of production of new graduates from their own colleges and universities.

Nationwide, 38 percent of students graduating with a bachelor's degree in science or engineering leave the state shortly after graduation. For newly trained Ph.D.s, 64 percent take their first jobs out of state. Stay rates for Arizona's universities are generally above the national average. Among those who received an undergraduate degree in a science or engineering field at some point since 2000, the percentages with a current Arizona residence are: 72 percent for graduates of Arizona State University, 66 percent for graduates of the University of Arizona and 64 percent for those graduating from Northern Arizona University. Among ASU graduates who received a master's degree or Ph.D. in an S&E field, 47 percent are still in state. Only 24 percent of U of A graduates with advanced S&E degrees have a current Arizona residence.

While Americans are highly mobile, there is still a "localness" to state markets for S&E workers. A much higher percentage of students take jobs and remain in the vicinity of their university than would be expected in a "flat" world where geography was unimportant. This is especially true for undergraduates. Even among newly trained S&E Ph.D.s, stay rates in major states are 4-10 times higher than one would expect in a frictionless national market.

Why do many college graduates stay and find jobs in the same city or state as their school? Students with family who were born in or attended high school in the same area as the university they attend may have a strong preference for sticking around. There is also evidence that the presence of a university, especially a top-rated research university, serves to attract high-tech employers, creating the jobs graduates need. Industrial R&D operations are seriously constrained by the labor market for scientists and engineers, and availability of scientific labor is an important consideration in the siting of an R&D facility. It is not only the students but the faculty at top research universities that stimulate local high-tech activity. University faculty who pioneered breakthrough discoveries in integrated circuitry, recombinant DNA and nanotechnology were heavily involved in the transfer of that knowledge to industry and served as magnets for new firms wishing to develop the new technology.

## Employment and Earnings of S&E Workers in Arizona

Arizona is a relatively science and engineering intensive state. Science and engineering workers account for 5.4 percent of total Arizona employment, which is slightly higher than the 5.2 percent share of S&E workers in U.S. employment.

Engineering occupations are particularly well represented in Arizona. The state accounts for 2.2 percent of U.S. workers in architecture and engineering occupations, as compared with a 1.9 percent share of all U.S. workers. Arizona ranks 13th highest among the 50 states and the District of Columbia in share of state employment accounted for by architects and engineers. The representation of engineers in the state's economy is particularly high in aerospace, electrical and electronics, materials and computer hardware. Among Western states, Arizona is less engineering intensive than Washington, New Mexico, Colorado and California, but more engineering intensive than Utah, Oregon and Nevada.

Arizona ranks 17th highest in the nation in shares of state employment accounted for by workers in computer and mathematical occupations and 27th among the states in shares of science employment.

Wage levels are an indicator of labor scarcity. By comparing Arizona wages with U.S. wages, it is possible to gain some insight into the question of whether Arizona firms have been unusually handicapped in their search for qualified S&E workers. Wages have always been lower in Arizona than in the nation, but this is partly attributable to a preference workers have for living in regions with a warm and dry climate. Labor shortages at the state level for a given occupation group may manifest themselves not through wages that are higher in the state than in the nation, but in a state/national wage differential that is higher than the average differential across all occupations.

In 2000, the average ratio of Arizona wages to U.S. wages was 94 percent when looking across all of the 22 major occupational groups in the economy. The ratio for computer and mathematical occupations was 3rd highest among the 22 groups. The wage ratio for workers in architecture and engineering occupations was 4th highest. Neither of these ratios was above 100 percent, but each was significantly above average. In 2010, the ratios of Arizona wages to U.S. wages were again above average in computer-related and engineering occupations, but by a smaller margin. The ratio for architecture and engineering occupations was 6th highest among the 22 groups, and the ratio for computer and mathematical occupations was 9th highest. In both 2000 and 2010, the ratio of Arizona to U.S. wages for workers in life, physical and social science occupations was well below the average across all occupations.

If wages are used as an indicator of labor scarcity, there is some evidence that Arizona may have faced greater shortages of scientists and engineers than was typical across the nation. This seems to have been truer in 2000 than in 2010. Any Arizona-specific shortages of S&E workers were limited to computer scientists and engineers. There is no indication that the state has faced shortages of workers in life, physical and social science occupations, outside of health care practitioners.

## The Training of Scientists and Engineers in Arizona

When compared with the size of its population, Arizona produces relatively few science and engineering graduates. In 2000, Arizona accounted for 1.83 percent of the U.S. population but only 1.41 percent of the nation's S&E bachelor's degrees and 1.50 percent of the nation's graduate degrees. Since 2000, there has been a decline in the ratios of Arizona's degree shares to its population share. In 2009, Arizona accounted for 2.15 percent of the nation's population but only 1.51 percent of U.S. bachelor's degrees and 1.54 percent of U.S. graduate degrees.

Looking at degrees by major field group, Arizona in 2009 accounted for 1.45 percent of U.S. degrees in computer science and mathematics, 1.78 percent of U.S. degrees in architecture and engineering, and 1.51 percent of U.S. degrees in life, physical or social science. Each of these percentages is significantly lower than the state's share of the national population.

In trying to assess whether local area firms are constrained by a low supply of S&E graduates, it is more accurate to benchmark the flow of new graduates in a state to the size of the S&E workforce instead of to the size of the resident population. Conclusions regarding adequacy of local supply are drawn by comparing the ratio of new graduates to workers in a state with the national average. The calculated ratios are indexed relative to the nation. An index value lower than 100 means that, when compared with the size of its S&E workforce, the flow of new S&E graduates in a state is below the national average. States with index values below 100 tend to be net importers of scientists and engineers, and companies located in these states tend to have a relatively difficult time recruiting S&E workers.

In 2000, Arizona produced relatively few science and engineering graduates in relation to the size of its S&E workforce. Index values in that year were 93 for computer scientists and mathematicians, 88 for architects and engineers, and 95 for all other scientists. Indexes measuring adequacy of local supply were also below 100 in almost all Western states. For California, Colorado and Washington – Western states with especially large S&E employment – the indexed ratios of new graduates to employed workers were significantly lower than those for Arizona.

Results for 2009 indicate that flows of new S&E graduates in Arizona have declined further relative to the size of the local workforce. The state's index values for computer scientists and engineers have fallen into the low 80s.

These results are consistent with a description of the Arizona job market in which local firms have a relatively hard time finding qualified science and engineering workers and must rely more than the average U.S. employer on S&E workers who have migrated to the state. In view of the success states such as California, Colorado and Washington have had in creating jobs for and recruiting S&E workers, it is clearly not necessary for a state to rely exclusively or even primarily on local colleges and universities to meet its S&E manpower needs. Nevertheless, states that are relatively small producers of S&E graduates will be somewhat labor constrained, especially if they do not have a market area, climate or other amenities that make it easy to attract S&E workers from other states.

Can suppliers of technology talent ease those labor constraints? The report explores the ways in which suppliers of technology talent 1) connect that talent with employers and 2) augment the supply of technology workers to meet firms' demands. First considered is how Arizona's universities and community colleges connect students with degrees in technology-related fields to employers. Career services departments at those educational institutions offer many of the services one would normally think of: hosting career fairs and other events, maintaining online job and résumé databases, holding workshops on résumé writing and interview skills, etc. They also offer a number of programs designed specifically around what firms have said they need – including hands-on experience opportunities for students. And, in many cases, the universities work closely with businesses to facilitate industry's input into educational programs. This is not a discussion about colleges and universities taking steps to produce more S&E workers, but rather a discussion of what they can do to ease asymmetries that might exacerbate labor constraints.

The report also considers the ways in which workforce development and training programs can actually augment the supply of technology workers to ease labor constraints. As is discussed in Chapter 6, after drilling down into the qualifications that firms seek, it becomes clear that firms often struggle with finding "qualified" talent. Arizona's workforce development and training programs can help fill that gap by offering technology workers training programs designed to provide new skills (and the certifications to go with).

## Survey and Interviews with Local Technology Companies

A primary objective of this project was to survey local technology firms to document the hiring practices and recruiting experiences of departmental managers who have hired scientists and engineers to work in Arizona. Follow-up interviews were also conducted to clarify and provide more detail on the survey responses of large companies and a sample of smaller ones.

The target of the survey was companies in Arizona who are involved in innovation – companies that employ scientists and engineers to carry out applied research and product development – *producers* of new technology, rather than *users* of it. When inquiring about the hiring experiences of employers of engineers, the survey focused on companies whose business it is, for example, to develop new medical devices or new rockets for missile defense systems, as opposed to practitioners of engineering such as construction firms. When assessing whether the state faces a shortage of scientists, the survey focused on companies involved in medical research and companies that employ chemists to create new industrial products, for example, rather than organizations that employ scientists to deliver health care services.

- 172 individuals from a total of 141 Arizona companies responded completely to the survey. 134 respondents reported that they employ computer scientists. Together these companies employ 6,093 computer scientists in Arizona, which represents approximately 10 percent of total Arizona employment in computer-related occupations. The number reported would represent a much larger percentage of the computer scientists employed by the high tech companies targeted in the survey. Roughly one-half of the computer scientists reported in the survey were software engineers; 14 percent were programmers.
- There were 110 respondents who reported employing engineers. The total number of engineers reported by these respondents was 14,426, which is approximately 30 percent of total engineering employment in the state. The number reported would represent a much larger percentage of the engineers employed by the high tech companies targeted in the survey. Forty-two percent of the engineers reported in the survey were electrical and electronics engineers; 23 percent were mechanical engineers.
- Twenty-six respondents indicated that they employ life and physical scientists. The total number of scientists reported by these establishments was 740. Fifty-one percent of those scientists were chemists; 17 percent were physicists.

**Labor in the U.S. is mobile.** To set Arizona firms' demand against the supply of technology workers from other Arizona firms and Arizona universities is too restrictive. While most of the technology employers that were interviewed reported that they would prefer to source local talent rather than relocate candidates from other places, many firms said that getting candidates from other places was not a significant source of stress.

**What does a "qualified" candidate look like?** Firms are not just looking for *any* computer scientists or *any* engineers or *any* scientists. Within each occupational category, firms have criteria they use to define a "qualified" candidate. Qualification criteria reported by interviewees include at least 2-3 years of work experience; education; specific skill sets; hands-on experience; soft skills; foundational skills; and cultural fit.

**The survey indicates (and interviews affirmed) a strong preference for job candidates with work experience.** Survey respondents reported that only 23 percent of recent hires of computer scientists, 29 percent of recently hired engineers, and 19 percent of scientists were fresh graduates or had less than two years of work experience. Forty-four percent of the computer scientists, 33 percent of the engineers, and 59 percent of the scientists hired had more than five years of work experience.

**The vast majority of job candidates across all categories had at least a bachelor's degree.** Among computer scientists, only 13 percent had less than a 4-year college education; roughly 67 percent had a bachelor's degree, and 20 percent had either a master's or a Ph.D. Among engineers, only 10 percent had less than a 4-year college education; 61 percent had a bachelor's degree; and 29 percent have either a master's degree or a Ph.D. Among scientists, 81 percent have a master's degree or Ph.D. and the remaining 19 percent have a bachelor's degree.

**H1-B visa constraints.** Many firms are constrained by an inability to hire foreign nationals, who make up a sizable percentage of educated technology workers and an increasingly large percentage of graduates of master's- and Ph.D.-level programs in science, technology, engineering, and math (STEM).

**Where are qualified candidates coming from?** Arizona technology employers source their talent in a number of ways, including from other firms in Arizona; from other firms outside Arizona; from universities (in- and out-of-state); 2-year schools; internship programs; H-1B visa programs (for foreign nationals); workforce development and training programs; contract (temporary) agencies; and the military.

**Most recent hires came from within Arizona.** Forty-one percent of computer scientist hires came from outside Arizona (59 percent from in state). Thirty-nine percent of engineer hires came from outside Arizona (61 percent from in state). 46 percent of scientist hires came from outside Arizona (54 percent from in state). When survey respondents indicated that less than 50 percent of their recent hires came from out of state, they were asked why. Based on those responses, it was concluded that Arizona technology companies that do not recruit heavily from out of state don't do so more because there is sufficient local ability and because of the extra expense of recruiting out of state rather than because of a reluctance on the part of candidates to move to Arizona.

**Most recently hired fresh graduates came from universities and colleges outside of Arizona.** Among all computer scientists recently hired who were fresh graduates or had less than two years of work experience, 32 percent obtained their highest degree from an Arizona college or university. That percentage was higher for engineers (44 percent) and much lower for scientists (25 percent). Among employers of computer scientists and engineers, there is little in the survey to suggest that Arizona technology companies are failing to hire Arizona graduates because of a perceived lack of quality or skills. Among employers of scientists, the relatively high percentage of respondents indicating that Arizona graduates did not have the skills they were looking for can be interpreted more as a consequence of hiring in a specialized national market than as a judgment about the quality of Arizona programs.

**What is the process by which firms source qualified talent?** The processes by which Arizona firms access technology talent pools include university engagement; recruiting agencies (headhunters); job boards; referrals; and growing talent from within (build versus buy).

**Do firms have difficulty attracting qualified technology workers?** When asked, "How difficult it has been to attract qualified technology workers?" an equal percentage (23.5) of respondents said it was very difficult to find qualified computer scientists as said it was not at all difficult; 53 percent of respondents said it was "somewhat difficult" to attract qualified computer scientists. A similar percentage (52) reported it was "somewhat difficult" to attract qualified engineers; 15 percent reported attracting qualified engineers was "very difficult" and 33 percent said "not at all difficult." Among respondents employing scientists, 87 percent reported it was "somewhat difficult" to attract qualified talent; 11 percent said "very difficult" and 2 percent said "not at all difficult."

**Where does that difficulty lie?** For nearly every firm reporting difficulty attracting "qualified" technology workers there was some more nuanced explanation of their supply/demand gap. Not enough technology workers had the right skill sets, or not enough had five or more years of work experience, or not enough had requisite soft skills, or not enough lived in Arizona. Interviews did not suggest that Arizona's universities are simply not graduating enough engineers, computer scientists, or scientists. Though, they might not be graduating enough "A" students in those fields, or U.S. citizens in those fields, or students with the "right" specialized skills or hands-on experience.

**What are the root causes of that reported difficulty?** Interviewees were asked about the root causes of reported difficulty hiring qualified technology talent in Arizona. A number of potential underlying factors were considered, including quantity constraints (simply not enough tech workers); people don't want to move to Arizona; a lack of industry concentration in Arizona; and the H-1B issue (the candidates might be "qualified" but employers can't hire them).

**What are the potential solutions to those issues?** The range of possible actions for employers, policymakers, and educational institutions to take to remove the factors making it difficult to hire technology talent in Arizona were explored. The options explored for companies include realigning the recent graduate/experienced worker ratio and changing job requirements. Interviewees suggested that policymakers could develop "core" industries in the state and counter misperceptions about Arizona's schools. What might universities do to address the talent sourcing difficulty? The options discussed range from tailoring curricula to business needs to offering more hands-on experience.

# 1 Introduction

## 1.1 Background and Organization of Report

In December 2009, Steve Zylstra, President and CEO of the Arizona Technology Council, approached the Seidman Research Institute at Arizona State University about conducting a workforce study which would focus on the manpower needs of high-technology companies operating in Arizona.[2] Steve had heard repeatedly from some members of the Council about difficulties they have had recruiting scientists and engineers to work at their facilities in Arizona. Ever since the Soviet launch of Sputnik in the 1950s, recurring alarms have been sounded at the national level by the scientific community and executives of high-tech companies of impending shortages of science and engineering workers. Steve wanted to know whether the concerns he had been hearing were part of a broader "urban legend" or whether, in fact, many Arizona technology companies had been having an unusually difficult time locating qualified workers. He envisioned a survey of Arizona technology companies that would reveal and document their recruiting experiences. He was also interested in knowing whether the flow of new science and engineering graduates from Arizona's universities would be sufficient to meet the future manpower needs of the state's high-tech companies.

The Seidman Research Institute prepared a proposal for a research project that would provide an analysis of labor market conditions for scientists and engineers in Arizona. The project would include a survey of Arizona technology companies and selected on-site interviews designed to gather information about the recruiting practices and hiring experiences of Arizona's technology companies. In addition to asking in a general way about how difficult it has been for companies to find qualified technology workers, the survey and interviews would inquire about the experiences local companies have had recruiting science and engineering graduates from the state's colleges and universities. Were there sufficient numbers of local graduates, and did they have the necessary knowledge and skills? The Seidman Institute was also interested in learning about companies' experiences with out-of-state recruiting. Outside of the usual difficulties associated with distance, had companies encountered other recruiting obstacles, such as poor migrant perceptions about the quality of Arizona's primary and secondary schools?

In preparing the proposal, the Seidman Institute decided that it was important to broaden the project from what had been originally discussed. In addition to analyzing the primary data collected in company surveys and interviews, it would be useful to look at secondary data from government sources to learn about labor market conditions for scientists and engineers in Arizona. On a more fundamental level, it was important to broaden the geographic scope of the project. Because Americans are mobile, especially those with advanced technical degrees, there is a great deal of interdependence between state and regional labor markets. It is clearly not necessary, and it may not be economical, for a state to rely primarily on local educational institutions to meet the manpower needs of local industry. With this in mind, Seidman recommended that the report include a review of trends and issues in the national market for scientists and engineers. It was also important to provide an answer to the question of whether the size of the flow of newly trained

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[2] The Arizona Technology Council is a trade association which represents and supports high-tech companies in Arizona. The Council has over 600 members and is Arizona's largest technology organization. The Council promotes public policy initiatives which further the interests of its members, hosts educational forums and networking opportunities for the technology community, and recognizes businesses, entrepreneurs and legislators who help advance technology in the state. For more information about the organization, see their website at www.aztechcouncil.org

graduates from a state's colleges and universities contributes in a meaningful way to the size of the local S&E workforce. To help answer this question, the Seidman research team would collect information from the alumni offices of the three state universities on the residential locations of former science and engineering graduates. Finally, Seidman recommended that all sources of newly trained technology workers be considered – not just graduates of the three state universities, but also those receiving associate degrees from the community colleges and those acquiring skills through workforce development and other training programs.

The work undertaken in this 15 month long study was made possible with primary funding from the *American Recovery and Reinvestment Act* (ARRA) and through the support of the following organizations: U.S. Department of Labor, Department of Economic Security, Governor's Council on Workforce Policy and the Arizona Commerce Authority. Additional support was provided by Arizona State University and the Arizona Technology Council and its members.

The report is organized as follows:

- Chapter 2 provides a review of trends and issues relating to the national market for scientists and engineers. Data from the Bureau of Labor Statistics (BLS) on employment and wages of U.S. S&E workers are examined. Wage growth in science and engineering occupations is compared with wage growth in other occupations as a market test of whether labor shortages have been particularly severe in S&E occupations. This chapter also provides a discussion of the most important factor shaping long-run trends in the U.S. market for S&E workers: the rapid increase in science and engineering capabilities in other countries of the world.
- Chapter 3 concerns the mobility of S&E graduates and the extent to which the size of the S&E workforce in a state is influenced by the number of graduates coming from its colleges and universities. Data from National Science Foundation surveys are used to measure the extent to which U.S. graduates with advanced degrees in science and engineering obtain industry jobs in the same city or state as the institution from which they graduated. Information from the alumni records of Arizona State University, the University of Arizona and Northern Arizona University are used to estimate the stay rates of Arizona's S&E graduates. The chapter concludes that while there is certainly a great deal of interstate movement of technology workers, graduates of local colleges and universities remain in state with far greater frequency than would be expected in a "flat" world. In the long run, the training of a large number of university graduates in a state is associated with a large number of workers settling there.
- Chapter 4 presents descriptive statistics on the Arizona market for scientists and engineers. Bureau of Labor Statistics data on employment provide a measure of how S&E-intensive the Arizona economy is relative to other states in the nation. Data on wages of S&E workers provide a test for whether shortages of science and engineering workers have been more acute in Arizona than in the rest of the country.
- Chapter 5 provides information from the National Center for Education Statistics on the flow of new science and engineering graduates from colleges and universities in Arizona and other states. The data are reviewed with an eye towards determining whether Arizona technology companies might be handicapped in their recruiting of S&E workers by a low rate of production of new graduates in the state.
- Chapter 6 presents results from the survey and follow-up interviews of Arizona high-technology companies. The survey and interviews solicit information directly from the

companies on their recruiting practices and hiring experiences. Respondents were asked about the difficulties they have had recruiting scientists and engineers to work in Arizona. The survey asked specifically whether managers have been dissatisfied with either the number or the quality of graduates from Arizona's institutions. Respondents also were queried about whether they have had difficulties with out-of-state recruiting, other than the usual issues related to distance.

- Chapter 7 summarizes the principal conclusions of the report.

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| David Wagner, ON Semiconductor | Philip Woudenberg, iT1 |
| Dawn Tebelak, Jabil | Pierre Landau, PhD, Polymap Wireless |
| Deb Hertle, OneNeck IT Services | Randy Eckel, ImageTag, Inc |
| Debi Caron, Trans-West Network Solution | Raphael Soetan, Marvell Semiconductor |
| Dennis Genge, Regenesis Biomedical | Ray Moralez, Forensics Consulting Solutions |

| | |
|---|---|
| Derek Neighbors, Integrum Technologies | Rich Hlavka, Lumension Security |
| Donald Loper, The Boeing Company | Richard M. Saldivar, Teris - Phoenix |
| Doug Floyd, Results Direct | Rick Winterich, Ensynch, Inc. |
| Doug Nicholas, Hard Dollar Corp. | Robert Interdonato, XO Communications |
| Douglas L. Wahl, The Janzen Wahl Group, LLC | Robert Mercer, Institute for Scientific and Space Research, Inc. |
| Douglas Limbaugh, Kutta Technologies, Inc. | Rodney J. Fuller, Fennemore Craig, PC |
| Dr. Kevin Garcia, Breault Research Organization, Inc. | Roger Vogel, Vante Medical Technologies |
| Duke Merhavy, Able Information Technologies, Inc. | Ron Michaels, The Stratford Group, Inc. |
| Ellen Howlett, AGM Container Controls, Inc | Ryan George, simpleview, inc. |
| Eric Miller, PADT, Inc. | Sasha Neuenschwander, GE Healthcare |
| Ervin R. Frazier, Rincon Research Corporation | Sergio R. Penaloza, Cox Communications |
| Ethan Abrams, iLinc | Sindi Major-Martinez, Sindel Technologies, LLC. |
| Forrest Blair, Virtuon | Stan Hartman, Pacific Scientific Energetic Materials Co. |
| Frances Thomas-Caldwell, Multitest | Stella Galaviz, Flinn |
| Frederick Claus, Solid Concepts, Inc | Stephan Demmer, NXP Semiconductors |
| George Hays, Arizona Instrument LLC | Stephan Zajac, Prescio Consulting, LLC |
| Gina Coppola, Avnet | Stephen Roberts, MesaBio |
| Grant Farrell, Kinetic Muscles, Inc. | Steve Kelly, Honeywell Aerospace |
| Gregg Creaser, Speedie & Associates | Steve Pagnucco, Universal Avionics |
| Hamid Shojaee, Axosoft, LLC | Steve Sanghi, Microchip Technology Inc |
| Ian McClarty, Phoenix NAP LLC | Steve Shiflett, Flodraulic Group Inc |
| Ivan Farias, Jabil Circuit | Steven Dwyer, EV Group |
| Jaewon Lim, The University of Arizona - Office of University Reserach Parks | Sushil Singh, Solugenix Corporation |
| James Hatch, Marvell Semiconductor | Ted Tessier (CTO), Flip Chip |
| James Marzola, AbilityCRM | Tom Maples, DPR Construction |
| James McDonald, Cactus Custom Analog Design Inc. | Tony Goen, KinetX, Inc |
| James Ratcliff, Rowpar Pharmaceuticals | Traci Blackstone, Axway |
| Jan Davis for Jeff Martin, Yulex Corporation | Travis Eckerode, Securplane |
| Jason Giachino, Hypercom | Travis Lass, Xlcon |
| Jeff Quisenberry, CH2M HILL | Vanessa Bluem, CIBER, Inc. |
| Jenna Elmer, Paragon Space Development Corporation | Venicha Smith, GE Healthcare |
| Jennifer Monnig, Intel Corp | Victor Berrios, Freescale Semiconductor |
| Jeremy Govier, Edmund Optics | Wendy Schmidt, Marvell Semiconductor |
| Jerry Fuentes, AT&T | Wendy Whitman, Marvell Semiconductor |
| Jessica Dement, Forensics Consulting Solutions | William Wells, HDR Architecture, Inc |
| Jim Caravella, NXP Semiconductors | Yani Deros, President, ATOMdesign |
| Jim Duckett, Net Fusion Services | Ken Arnold, Avnet |
| Jim Kaiser, J-Curve Technologies | Taralee Brady, Go Daddy |
| Jim Siragusa, Enterprise Technology Services | Bob Smith, Honeywell |
| Jim Spehar, NXP Semiconductors | Deanna Laird, IBM |
| Jim Sweetman, Raytheon Missile Systems | Cathy Burnes, Infrared Laboratories (IRLabs) |

| | |
|---|---|
| Joanne Carthey, Namescape Corporatiion | Brett Gilliland, Infusionsoft |
| John Allen, CyberTrails, LLC | Anthony Padilla, Intel |
| Jon Catlin, Syntellect | Kalani Ching, Intel |
| Jon Steging, MicroBlend, Inc. | Jeff Dunn, Intel |
| Karen Legge, Celgene Corporation | Kianoush Rahbar, Intel |
| Kathryn Charlton, General Dynamics C4 Systems | Jeff Slaton, Intel |
| Kathryn Odland, Global Patent Solutions, LLC | Kjell Stakkestad, KinetX, Inc |
| Kathy Collins, Site Chief Engineer, The Boeing Company | Steve Pedigo, Northrop Grumman |
| Kelly Kayser, ON Semiconductor | Chris Hardy, ON Semiconductor |
| Ken Colburn, Data Doctors | Hans Stork, ON Semiconductor |
| Ken Marlin, Avnet | Chuck Vermillion, OneNeck IT |
| Kevin Barnett, End 2 End Technologies | Kerry Heil, Orbital Sciences Corporation |
| Kevin Goates, Northrop Grumman | Pam Hennard, Perot Systems (Dell) |
| Kyle Ferrio, Ph.D., Breault Research Organization | Bob Lepore, Raytheon |
| Larry Gentry, Custom Storage | Sherman Jennings, The Boeing Company |
| Lauren Patel, Sage | Herb Rosen, Trans-West Network Solution |

### 1.2.3 Other Interviewees

A number of individuals graciously lent their time and insight into the ways in which Arizona's universities and community colleges connect technology students with employers, including:

- Elaine Stover, Career Services Director, Arizona State University
- Robin Hammond, Director, Engineering Career Center, Ira A. Fulton Schools of Engineering, Arizona State University
- Monica Bai, Assistant Director, Gateway Student Success Center Northern Arizona University
- Eileen McGarry, Director of Career Services, University of Arizona
- John Catapano, Coordinator, Research and Communications, Maricopa Community Colleges
- Rick Hansen, Associate Director, Center for Workforce Development, Maricopa Community Colleges
- Matt Kim, CEO, QuantTera
- Tom McGlew, Instructional Programs Development Specialist, Maricopa Advanced Technology Education Center
- Trevor Thornton, Director of the Center for Solid State Electronics Research, ASU Fulton Schools of Engineering
- Ray Tsui, President, Raydis LLC

A number of individuals graciously lent their time and insight into the ways in which Arizona's workforce development and training programs connect technology workers with employers, including:

- Rosalyn Boxer, Workforce Director, Arizona Commerce Authority
- Kirsten Hall, Workforce Manager, Arizona Commerce Authority
- Mary Wolf-Francis, Business Liaison, Phoenix Workforce Connection
- Diana Shepherd, Operations Manager, Maricopa Workforce Connection

# 2 The National Market for Scientists and Engineers

## 2.1 Overview

This is principally a report about the science and engineering workforce in Arizona. Because of the high mobility of American workers, however, state and regional labor markets are interdependent. It can be argued that the market for S&E workers is a national, if not international one. With this in mind, a good place to start when providing context and background for an assessment of S&E workforce issues in Arizona is with national trends.

Section 2.2 of this chapter reviews historical trends in U.S. employment of scientists and engineers. Major conclusions relating to changes in the number of employed S&E workers are summarized below.

- Computer-related occupations have shown the fastest employment growth over the past several decades. In 1970 computer and mathematical occupations accounted for only 0.5 percent of the U.S. labor force. By 2000 this percentage had more than quadrupled to 2.2 percent. Since 2000, employment in computer-related occupations has increased by 12 percent. The largest employment gains have been in software development and network and systems administration. Employment of computer programmers, on the other hand, has declined by nearly 200,000 jobs.

- Since 1990, total employment in architecture and engineering occupations has declined absolutely, and its share of the labor force has fallen from 2.2 percent to 1.8 percent. Some occupations have registered strong employment gains, including petroleum engineers and construction-related occupations like architecture and civil engineering. But the nation has suffered heavy job losses in occupations related to electronics and electrical engineering.

- Over the past two decades, employment in life, physical and social science occupations has increased in absolute terms but fallen slightly as a percent of the labor force. Occupations with solid employment gains include biochemists, medical scientists and environmental scientists. Employment of chemists and psychologists, on the other hand, has declined.

More notable than changes in the level of S&E employment have been changes in the demographic makeup of workers. Increases in employment of female and foreign-born S&E workers have offset a sharp decline in the number of native-born male workers. Foreign-born workers have become critical to the highly educated S&E workforce. More than half of all architects and engineers with a Ph.D. are foreign born. Roughly one-half of U.S. workers in computer and mathematical occupations who have a Ph.D. are foreign born.

The rise in the foreign-born share of U.S. scientists and engineers over the past two decades has been made possible by a liberalization of U.S. immigration laws targeting highly educated skilled workers. Particularly important in this regard has been the creation of the H-1B temporary worker visa which allows U.S. employers to recruit foreign workers in occupations such as computer programming and engineering. U.S. immigration policy has certainly not been free. But the H-1B visa has had a profound impact on the highly educated S&E workforce in the United States.

Section 2.3 of this chapter reviews trends in the wages of U.S. S&E workers. Inflation-adjusted wages in science and engineering occupations fell on average during the 1990s. Since 2000, wage increases in S&E occupations have been faster than the rate of inflation and above or near the average across all occupations in the economy. However, S&E wages have risen at a considerably slower pace than wages earned by people in management positions and health care practitioners. Among S&E workers, architects and engineers have experienced the fastest wage growth. But wage growth of a similar magnitude has also been recorded in other skilled occupations, including law and business and financial operations.

Among workers with advanced S&E degrees, those with Ph.D.s in math and engineering earn significantly more than those with a Ph.D. in the life, physical or social sciences. Even highly compensated, doctorate-level engineers, however, earn considerably less than workers with advanced professional degrees. Medical doctors earn 72 percent and lawyers 26 percent more than do engineers with a doctorate degree. For students deciding on a career requiring advanced education, significantly higher financial rewards can be expected in professional occupations than in science or engineering occupations.

Ever since the Soviet launch of Sputnik in the 1950s there have been recurring claims made by the scientific community and executives of high-tech companies of shortages of S&E workers. In the minds of economists, labor shortages are self-correcting and temporary. If at going wages, businesses want to hire more scientists and engineers than are currently available, then competition between employers will force wages up, and this will serve to eliminate the shortage. The statistical evidence reviewed here clearly shows that U.S. wages and salaries of scientists and engineers have lagged behind those in other occupations requiring a high level of training and education. If rapidly rising pay is the primary indicator of a labor shortage, then the country faces more acute shortages of business executives and managers, doctors and pharmacists, lawyers and financiers.

Instead of talking about general labor shortages, it would be more accurate to say that the U.S. has an adequate supply of scientists and engineers but only because of a sizeable influx of foreign-born students and technical workers. The U.S. is not experiencing a shortage of scientists and engineers but of native-born entrants into these fields. The question is whether anything should be done about it. For young Americans to choose careers in science and engineering rather than medicine, law or finance, wages in S&E occupations must rise significantly. But if they do, many of these jobs will go overseas.

Section 2.4 provides a discussion of the most important factor shaping long-run trends in the U.S. market for S&E workers – the rapid increase in science and engineering capabilities in other countries of the world. Global developments, especially trends toward mass higher education in highly populated developing countries, are eroding U.S. dominance of science and technology. Since 1970, the U.S. share of world enrollments in higher education has fallen from 29 percent to 12 percent. Higher education in developing countries has exploded. Since 2000, tertiary education enrollments in developing countries have increased from 66.9 million to 126.6 million. The less developed world now accounts for 77 percent of the world's population of students enrolled in institutions of higher education. In China alone the number enrolled in tertiary education has increased from 7.4 million to 29.3 million, which is 53 percent larger than current U.S. enrollments.

American consumers benefit from advances in technology, regardless of where they are made, or by whom. The downside to technical advance in foreign countries is that the U.S. will suffer an erosion of its comparative advantage in developing and manufacturing high-tech goods. The costs of adjusting to increased competition from countries like China and India are likely to be more significant than those associated with economic recovery in Europe and Japan following WWII. The question is what the U.S. should do to minimize these adjustment costs.

The policy area that is most critical in determining the path of U.S. adjustment is immigration. Is it better to recruit more foreign students and technical workers from the world's labor pool, or force U.S. multinationals to compete by offshoring an increasing amount of high-tech production and research? Immigration preferences for foreign-born students would play to the strong competitive advantage the U.S. enjoys in graduate-level education. Knowledge spillovers also favor immigration over offshoring. Productivity in the domestic workforce is better served by allowing the local population to work with highly educated foreign workers instead of just buying goods from them.

## 2.2 U.S. Employment of Scientists and Engineers

### 2.2.1 Historical Trends

Exhibit 2.1 provides information on long-term trends in S&E employment in each of three broad occupational groups: computer and mathematical occupations (Standard Occupational Classification 15), architecture and engineering occupations (SOC 17), and occupations in the life, physical and social sciences (SOC 19). Employment is expressed in both absolute numbers and as a percent of the national labor force. The data are from the decennial censuses of 1970-2000 and, most recently, the last five years of the American Community Survey.

## Exhibit 2.1: Long-Run Trends in U.S. Science and Engineering Employment

| | 1970 | 1980 | 1990 | 2000 | 2005-2009 |
|---|---|---|---|---|---|
| **Computer and mathematical occupations** | | | | | |
| Number employed | 405,059 | 702,721 | 1,563,769 | 3,168,447 | 3,351,542 |
| % of labor force | 0.49% | 0.66 | 1.24 | 2.23 | 2.19 |
| **Architecture and engineering occupations** | | | | | |
| Number employed | 1,911,723 | 2,290,752 | 2,745,384 | 2,659,298 | 2,716,988 |
| % of labor force | 2.31% | 2.14 | 2.18 | 1.87 | 1.78 |
| **Life, physical, and social science occupations** | | | | | |
| Number employed | 592,000 | 907,116 | 1,254,975 | 1,203,443 | 1,328,756 |
| % of labor force | 0.71% | 0.85 | 1.00 | 0.85 | 0.87 |
| **All S&E occupations** | | | | | |
| Number employed | 2,908,782 | 3,900,588 | 5,564,128 | 7,031,188 | 7,397,286 |
| % of labor force | 3.51% | 3.64 | 4.43 | 4.94 | 4.83 |

***Source:*** *U.S. Bureau of the Census, decennial census and the American Community Survey*

In economic theory, employment is an equilibrium outcome of a competitive labor market process in which wages adjust to balance the demand for workers with the supply. Increases in employment are the result of an increase in the demand for S&E workers, an increase in the supply of workers, or some combination of the two. Decreases in employment result from either a decrease in demand or a decrease in the supply of labor.

Of the three broad S&E occupational groups, computer and mathematical occupations have shown the fastest employment growth over the past four decades. In 1970 computer and mathematical occupations accounted for only 0.5 percent of the U.S. labor force. By 2000 this percentage had more than quadrupled to 2.2 percent. Since 2000 employment in computer and mathematical occupations has increased by approximately 180,000 workers and still represents about 2.2 percent of the labor force. The demand for workers in this occupational category has been driven by the IT revolution. Information technology has become an integral part of every sector of the economy. Virtually every business now supports either directly or indirectly jobs performed by computer programmers, software developers, systems analysts and network administrators. The growing demand for computer-related workers has been met by an increase in labor supply – from both native workers and foreign-born workers, the latter made possible by targeted liberalizations in U.S. immigration policy (see Section 2.2.3).

Employment in architecture and engineering occupations increased by 830,000 workers from 1970 to 1990 and represented approximately 2.2 percent of the labor force in each of those years. Since 1990, however, architecture and engineering employment has declined slightly in absolute terms, and its share of the labor force has fallen to 1.8 percent. The relative decline in this category of employment is due partly to demand-side factors, including rapid gains in labor productivity in industries such as semiconductor manufacturing that employ large numbers of engineers, and shifts in comparative advantage which have led to the relocation of manufacturing and research facilities to foreign countries. The decline in employment also reflects a decrease in the supply of native workers to these occupations. Opinion is divided over whether the decrease in supply is because younger generations are unwilling or unable to endure the rigors of training in highly mathematical fields such as engineering or whether it simply represents a response to greater financial rewards in other occupations requiring high levels of education. Information on the relative earnings of scientists and engineers will be presented in Section 2.3.

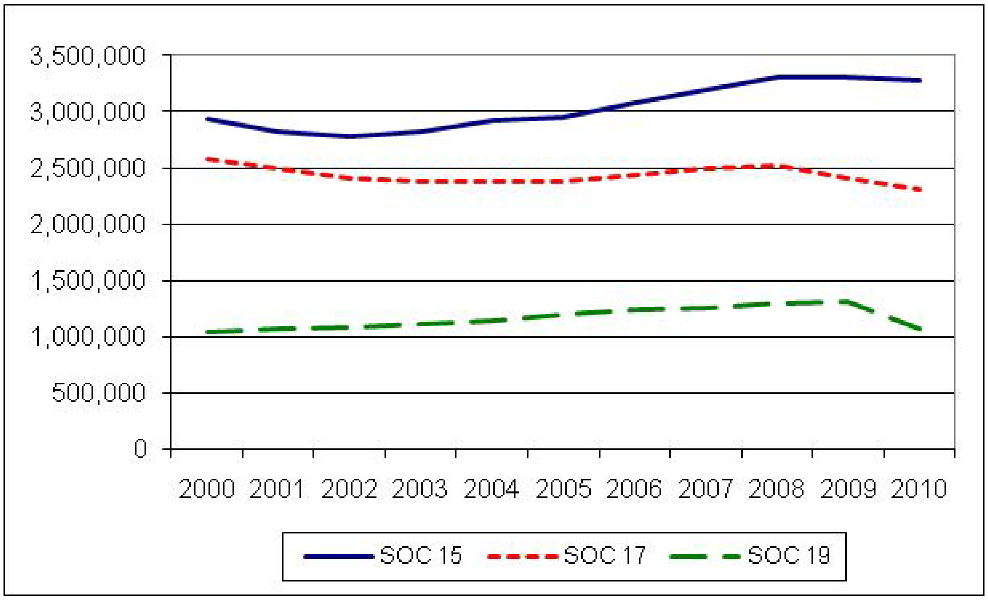
Since 1970 employment in occupations involving life, physical or social sciences has increased by approximately 750,000 workers. As a percent of the labor force, science occupations have grown from 0.7 percent to 0.9 percent. Almost all of the job growth occurred from 1970-1990. Since 1990, absolute employment in life, physical and social science occupations has increased only 70,000 workers, and the percent of the labor force represented has fallen by 0.1 percent.

Altogether, science and engineering employment in the United States has increased by 4.5 million workers since 1970. As a share of the U.S. labor force, S&E employment has increased from 3.5 percent to 4.8 percent. The overall growth in S&E employment has been driven by rapid growth in computer-related occupations.

Exhibits 2.2 and 2.3 provide alternative information on science and engineering employment from 2000-2010. The data are from special occupational employment and wage surveys of business establishments conducted by the Bureau of Labor Statistics in cooperation with State Workforce Agencies. The surveys do not count the self employed.

Shown in Exhibit 2.2 are S&E employment levels for each year from 2000-2010. The effects of the recent recession are apparent in each category of employment. Over the entire decade, the BLS data tell a story similar to the one revealed in census data. The fastest growing S&E segment has been computer and mathematical occupations. Employment in this category increased 12 percent from 2000 to 2010. Employment in life, physical and social science occupations also increased over the period, but by only 2 percent. Architecture and engineering employment fell by 270,000 jobs (or 10 percent) from 2000 to 2010.

### Exhibit 2.2: U.S. Employment in Major S&E Occupational Groups, 2000-2010




***Source:*** *BLS, Occupational Employment Statistics*

Exhibit 2.3 provides information by detailed occupational category on science and engineering employment in 2000 and 2010. Among computer and mathematical occupations, the strongest employment growth occurred in software development and network and systems administration. Employment of computer programmers, on the other hand, dropped by nearly 200,000 jobs (or 37 percent) from 2000 to 2010. Contributing to this decline was an outsourcing of computer programming jobs to India and other foreign countries.

### Exhibit 2.3: U.S. Science and Engineering Employment by Detailed Occupation, 2000 and 2010

| Occ Code | Occupation | 2000 Employment | 2010 Employment | Percent Change |
|---|---|---|---|---|
| **15-0000** | **Computer and Mathematical Occupations** | **2,932,810** | **3,283,950** | **12.0%** |
| 15-1121 | Computer Systems Analysts | 463,300 | 495,800 | 7.0 |
| 15-1131 | Computer Programmers | 530,730 | 333,620 | -37.1 |
| 15-1132 | Software Developers, Applications | 374,640 | 499,280 | 33.3 |
| 15-1133 | Software Developers, Systems Software | 264,610 | 378,920 | 43.2 |
| 15-1141 | Database Administrators | 108,000 | 104,080 | -3.6 |
| 15-1142 | Network and Computer Systems Administrators | 234,040 | 333,210 | 42.4 |
| 15-1150 | Computer Support Specialists | 522,570 | 579,270 | 10.9 |
| 15-2031 | Operations Research Analysts | 59,820 | 62,210 | 4.0 |
| **17-0000** | **Architecture and Engineering Occupations** | **2,575,620** | **2,305,530** | **-10.5** |

| | | | | |
|---|---|---|---|---|
| 17-1011 | Architects, Except Landscape and Naval | 74,390 | 87,700 | 17.9 |
| 17-2011 | Aerospace Engineers | 71,550 | 78,450 | 9.6 |
| 17-2041 | Chemical Engineers | 31,530 | 28,720 | -8.9 |
| 17-2051 | Civil Engineers | 207,080 | 249,120 | 20.3 |
| 17-2061 | Computer Hardware Engineers | 63,680 | 66,960 | 5.2 |
| 17-2071 | Electrical Engineers | 162,400 | 148,770 | -8.4 |
| 17-2072 | Electronics Engineers, Except Computer | 123,690 | 133,660 | 8.1 |
| 17-2112 | Industrial Engineers | 171,810 | 202,990 | 18.1 |
| 17-2131 | Materials Engineers | 24,430 | 21,830 | -10.6 |
| 17-2141 | Mechanical Engineers | 207,300 | 234,400 | 13.1 |
| 17-2161 | Nuclear Engineers | 12,610 | 18,610 | 47.6 |
| 17-2171 | Petroleum Engineers | 10,250 | 28,210 | 175.2 |
| 17-3011 | Architectural and Civil Drafters | 92,610 | 89,670 | -3.2 |
| 17-3012 | Electrical and Electronics Drafters | 38,470 | 27,960 | -27.3 |
| 17-3013 | Mechanical Drafters | 69,620 | 64,440 | -7.4 |
| 17-3022 | Civil Engineering Technicians | 89,200 | 77,050 | -13.6 |
| 17-3023 | Electrical and Electronics Engineering Technicians | 244,570 | 147,750 | -39.6 |
| 17-3026 | Industrial Engineering Technicians | 65,220 | 61,630 | -5.5 |
| 17-3027 | Mechanical Engineering Technicians | 58,490 | 44,170 | -24.5 |
| **19-0000** | **Life, Physical, and Social Science Occupations** | **1,038,670** | **1,064,510** | **2.5** |
| 19-1021 | Biochemists and Biophysicists | 13,440 | 22,800 | 69.6 |
| 19-1022 | Microbiologists | 15,880 | 18,330 | 15.4 |
| 19-1042 | Medical Scientists, Except Epidemiologists | 35,570 | 93,560 | 163.0 |
| 19-2012 | Physicists | 8,990 | 16,860 | 87.5 |
| 19-2031 | Chemists | 82,320 | 80,180 | -2.6 |
| 19-2032 | Materials Scientists | 8,660 | 8,390 | -3.1 |
| 19-2041 | Environmental Scientists and Specialists, Including Health | 54,860 | 81,690 | 48.9 |
| 19-2042 | Geoscientists, Except Hydrologists and Geographers | 21,810 | 30,830 | 41.4 |
| 19-3011 | Economists | 13,680 | 13,250 | -3.1 |
| 19-3031 | Clinical, Counseling, and School Psychologists | 103,120 | 100,700 | -2.3 |
| 19-4021 | Biological Technicians | 41,660 | 72,940 | 75.1 |
| 19-4031 | Chemical Technicians | 74,240 | 59,440 | -19.9 |

***Source:** BLS, Occupational Employment Statistics*

While total employment of architects and engineers declined from 2000 to 2010, there were some individual occupational categories which registered strong growth. Most impressively, employment of petroleum engineers increased by almost 18,000 jobs (or 175 percent) over the period. Other categories showing strong employment growth are industrial engineers, mechanical engineers and occupations in construction-related fields such as architecture and civil engineering. Most notable among occupations registering declines in employment are jobs related to electronics and electrical engineering. Employment of electrical engineers declined by 13,500 jobs (or 8 percent) from 2000 to 2010. Jobs performed by electrical and electronics drafters decreased by 10,500 (or 27 percent). Most significantly, employment of electrical and electronics technicians fell by 97,000 jobs (or 40 percent). Much of the decline in employment in these categories is associated with the overseas relocation of manufacturing, testing and assembly of electronic parts and components.

The occupations in SOC 19 and the industries they serve are diverse. The three occupations in this category which registered the largest absolute employment gains are medical scientists (+58,000 jobs), biological technicians (+31,000 jobs) and environmental scientists (+27,000 jobs). Occupations showing smaller absolute gains but very large percentage gains include biochemists and biophysicists, physicists and geoscientists. Occupations which employ a large number of individuals and registered declines in employment over this period include chemists, chemical technicians and psychologists.

### 2.2.2 Changing Demographics: More Female and Foreign-Born S&E Workers

More notable than changes in the level of S&E employment have been changes in the demographic makeup of workers. Women have entered science and engineering occupations with much greater frequency. And over the past two decades, there has been a large influx of foreign-born workers. Foreign-born workers have become vital to the highly educated science and engineering workforce. The increase in female and foreign-born workers has served to offset a decline in native-born male workers. Without this offset, it would not have been possible to satisfy U.S. demand for science and engineering labor at current salary levels.

Exhibit 2.4 uses census data to document the rise in women's participation in S&E occupations since 1970. For comparison, the bottom row in the exhibit shows the female share of all U.S. workers 16 years and older. Science and engineering occupations have traditionally been male-dominated, and the female share of S&E jobs still remains well below the economy-wide average. But the gap has narrowed, especially during the period 1970-1990. The difference between the female share of all U.S. workers and the female share of S&E workers was 28 percent in 1970. By 1990 the gap had narrowed to 21 percent. From 1970-1990 women represented 10-25 percent of the S&E workforce, but accounted for 40 percent of its growth. Since 1990 women's share of S&E employment has stabilized, as it has in the general economy.

### Exhibit 2.4: Trends in the Female Share of U.S. Science and Engineering Employment (%)

| | 1970 | 1980 | 1990 | 2000 | 2005-09 |
|---|---|---|---|---|---|
| **S&E occupations** | **9.4** | **17.2** | **24.3** | **25.6** | **25.8** |
| Computer & mathematical occupations | 20.0 | 28.6 | 34.1 | 30.0 | 27.3 |
| Architecture & engineering | 4.4 | 9.4 | 12.9 | 13.4 | 14.5 |
| Life, physical and social sciences | 18.2 | 28.3 | 37.1 | 41.1 | 45.2 |
| **All employed persons 16 yrs and older** | **37.7** | **42.4** | **45.2** | **46.4** | **46.6** |

***Source:*** *Data for S&E occupations are from the decennial census and the 2005-09 American Community Survey. Data on the female share of all employed persons is from the Current Population Survey.*

Exhibit 2.5 uses census data to track the rising share of foreign-born workers in U.S. science and engineering employment. In 1970 only 8 percent of all S&E workers were foreign born. By 2000 that figure had risen to 18 percent, and the share is around 20 percent today. Foreign-born workers accounted for 44 percent of the growth in S&E employment from 1990-2000 and for 49 percent of the growth since 2000. The rise in foreign-born workers in S&E occupations was made possible by selective liberalizations in U.S. immigration policy, the details of which will be discussed in the next section.

### Exhibit 2.5: Trends in the Foreign-Born Share of U.S. Science and Engineering Employment (%)

| | 1970 | 1990 | 2000 | 2005-09 |
|---|---|---|---|---|
| **S&E occupations** | 7.6 | 11.4 | 18.3 | 19.8 |
| Computer & mathematical occupations | 4.8 | 10.3 | 19.3 | 22.0 |
| Architecture & engineering | 7.4 | 12.3 | 16.4 | 17.4 |
| Life, physical and social sciences | 9.8 | 10.3 | 20.0 | 19.4 |

***Note:*** *Data for 1970 and 1990 are based on an older occupational classification which includes post-secondary teachers.*
***Source:*** *Data for 1970 and 1990 are from the decennial census, as prepared and reported by T. Espenshade. Data for 2000 and 2005-09 are from the PUMS files for the 2000 Census and the 2005-09 American Community Survey.*[3]

As shown in Exhibit 2.6, foreign-born workers are especially prominent among highly educated science and engineering workers. While representing 20 percent of all S&E workers, the foreign born account for 33 percent of U.S. scientists and engineers with a master's degree and 41 percent of all S&E workers with a Ph.D. More than half (53 percent) of all architects and engineers with a Ph.D. are foreign born. And exactly one-half of U.S. workers in computer and mathematical occupations who have a Ph.D. are foreign born.

[3] T. Espenshade, "High-End Immigrants and the Shortage of Skilled Labor," Population Research and Policy Review, April 2001, Table 2, p.139.

### Exhibit 2.6: Foreign-Born Share of Individuals in S&E Occupations by Highest Degree (%)

| | 2000 | | | 2005-09 | | |
|---|---|---|---|---|---|---|
| | **Bachelor's** | **Master's** | **Doctorate** | **Bachelor's** | **Master's** | **Doctorate** |
| **S&E occupations** | **17.7** | **29.4** | **38.6** | **18.6** | **33.0** | **41.1** |
| Computer & mathematical occupations | 19.8 | 37.8 | 41.6 | 21.9 | 43.4 | 49.6 |
| Architecture & engineering | 16.0 | 27.7 | 51.5 | 16.4 | 30.3 | 53.3 |
| Life, physical and social sciences | 15.1 | 17.9 | 35.3 | 13.0 | 17.8 | 36.3 |
| **All other occupations** | **11.7** | **12.1** | **20.2** | **13.4** | **13.1** | **22.6** |

***Source:*** *2000 Census and 2005-09 American Community Survey PUMS data*

### 2.2.3 The H-1B Visa

The rise in the foreign-born share of U.S. scientists and engineers over the past two decades has been made possible by a liberalization of U.S. immigration laws targeting highly educated skilled workers. U.S. immigration policy over this period has certainly not been free. But the establishment and relaxation of special quotas for foreign workers in selective skilled occupational groups has had a profound impact on labor supplies in these areas.

Congress first responded to claims of impending shortages of skilled workers by passing the 1990 Immigration Act. This legislation increased the number of employment-based permanent resident visas and created a new temporary worker category (H-1B) to allow U.S. employers to recruit foreign workers in skilled "specialty occupations." The covered occupations include computer programmers, engineers, medical professionals and accountants. Admitted workers must have at least a bachelor's degree or its equivalent. The H-1B quota limit was set at 65,000 workers per year.

The limits on H-1B visas proved sufficient for most of the 1990s. However, visa shortages began to appear in FY1997 and FY1998. Congress relaxed the annual quota in 1998 with its passage of the American Competitiveness and Workforce Improvement Act. But even the new quota limits were quickly reached. Then, in response to pressure from universities and information-technology companies, Congress passed the American Competitiveness in the 21st Century Act of 2000 which raised the number of H-1B visas to 195,000 visas per year. The Act further liberalized visas for skilled workers by excluding from the cap anyone employed at a college, university or government research lab, and anyone for whom a petition is filed within 180 days after the person has attained a master's or doctorate degree from a U.S. institution.

The H-1B visa quota limit of 195,000 was never reached. However, the 2000 legislation called for a return in FY2004 to the old quota of 65,000, a level which remains in effect to this day. The H-1B Visa Reform Act of 2004 allows an additional 20,000 visas to be awarded to foreign workers with advanced U.S. degrees.

With the reduction in the H-1B quota beginning in FY2004, visa shortages have once again appeared. For FY2008, the entire basic quota was exhausted before the end of the first day on which applications were accepted, April 2. The additional 20,000 Advanced Degree H-1B visas were exhausted on April 30.
Exhibit 2.7 shows the top five major occupation groups served by H-1B petitions accepted in fiscal years 2008 and 2009. Computer-related occupations are far and away the most important category, accounting for 46 percent of all approved petitions. Other occupations highly represented among accepted H-1B petitions are engineering, college and university faculty, management and administration, and surgeons and physicians. The top three source countries by place of birth are India (52 percent), China (9 percent) and Canada (4 percent).

### Exhibit 2.7: H-1B Petitions Approved in FY 2008 and 2009: Top Five Major Occupation Groups

| Occupation Category | Number | Percent of Total |
|---|---|---|
| Computer-related occupations | 225,971 | 46.1% |
| Architecture and engineering | 55,340 | 11.3 |
| Education | 53,591 | 10.9 |
| Administrative specializations | 44,538 | 9.1 |
| Medicine and health | 35,399 | 7.2 |

***Source:*** *U.S. Department of Homeland Security*[4]

### 2.2.4 U.S. Doctorate Recipients

In the economics literature on science and engineering manpower issues, special emphasis has been placed on workers with a Ph.D. The doctorate degree is the critical degree for advanced research. Economists are generally agnostic about the particular makeup of economic activity in a country, arguing that it is in a nation's interest to allow the forces of international competition to force it to specialize in its areas of comparative advantage, whether they are in the manufacture of "computer chips or potato chips." But a case can be made for giving special consideration to research activity. The process of creating knowledge is prone to (local) spillovers, and this opens the intellectual door to advocating support for knowledge-based industries.

Within the general topic of U.S. workers with a Ph.D., particular attention has been focused on Ph.D.s granted by U.S. universities. Local production is not the only source of doctorate-level workers, of course. Approximately 10 percent of foreign-born U.S. S&E workers with a Ph.D. obtained those degrees overseas.[5] Nor do all individuals receiving degrees from U.S. institutions stay in the United States. Stay rates among foreign students are now around 65 percent.[6] Nevertheless, U.S. programs are the primary source of Ph.D.-level science and engineering workers in the United States. And special surveys conducted by the National Science Foundation of U.S.

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[4] U.S. Department of Homeland Security, Characteristics of H-1B Specialty Occupation Workers, FY 2009 Annual Report, Table 8A, p.11.
[5] R. Freeman and D. Goroff, "Introduction" in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment*, The University of Chicago Press, 2009.
[6] M. Finn, "Stay Rates of Foreign Doctorate Recipients from U.S. Universities," Oak Ridge Institute for Science and Education, Oak Ridge, Tennessee, Working Paper, 2007.

doctorate recipients provide much detailed information on their demographic characteristics and earnings experiences.

One of the most significant trends in U.S. science and engineering doctorate programs is the shifting demography of degree recipients. Over the past four decades there has been a sharp decline in the percent of Ph.D.s obtained by native-born males (e.g., white males) and an offsetting rise in the shares of Ph.D.s earned by native-born women and foreign students. These trends are illustrated in Exhibit 2.8 using data on U.S. doctorate awards over five-year periods broken out by sex, citizenship and residency status.

### Exhibit 2.8: Gender and Citizenship Status of New U.S. Science and Engineering Ph.D.s, by 5-year Cohort

| | 1975-79 | 1980-84 | 1985-89 | 1990-94 | 1995-99 | 2000-04 |
|---|---|---|---|---|---|---|
| **Number of science and engineering Ph.D.s** | **84,591** | **85,785** | **92,572** | **118,568** | **127,066** | **121,325** |
| U.S. citizen and permanent resident | | | | | | |
| Male | 56,929 | 50,614 | 47,398 | 52,036 | 55,264 | 46,072 |
| Female | 14,155 | 19,171 | 22,171 | 28,593 | 34,408 | 34,413 |
| Temporary resident | 13,507 | 16,000 | 23,003 | 37,939 | 37,394 | 40,840 |
| **Percent of total** | | | | | | |
| U.S. citizen/perm res and male | 67.3% | 59.0 | 51.2 | 43.9 | 43.5 | 38.0 |
| U.S. citizen/perm res and female | 16.7% | 22.3 | 24.0 | 24.1 | 27.1 | 28.4 |
| Temporary resident | 16.0% | 18.7 | 24.8 | 32.0 | 29.4 | 33.7 |

***Note:*** *In NSF totals, S&E doctorates include Ph.D.s in psychology and health sciences.*
***Source:*** *NSF, Survey of Earned Doctorates*

Over the five-year period 1975-79, approximately 56,900 science and engineering Ph.D.s were awarded to men who were either U.S. citizens or had permanent resident status. The rate of awards to men in this category declined sharply during the 1980s, recovered partially during the 1990s, but then fell again to a new low of around 46,100 over the period 2000-04. More strikingly, out of all the science and engineering Ph.D.s awarded by U.S. institutions, the percent awarded to males with U.S. citizenship or permanent resident status has declined from 67 percent in 1975-79 to 38 percent in 2000-04.

Despite the decline in the number of native-born men receiving S&E Ph.D.s, there has been a significant increase in total S&E Ph.D. awards at U.S. universities. Looking again at degrees awarded over five-year periods, the total number of new S&E Ph.D.s increased by 43 percent from 1975-79 to 2000-04. The overall increase in new Ph.D.s was made possible by gains in Ph.D.s received by foreign students and native-born women. The number of science and engineering Ph.D.s awarded to students with temporary residence status rose from around 13,500 over the period 1975-79 to 40,800 by 2000-04. The share of new S&E Ph.D.s accounted for by temporary residents rose from 16 percent to 34 percent. At the same time, the percent of new S&E Ph.D.s going to women who were either U.S. citizens or had permanent resident status increased from 17 percent to 28 percent.

The trend of growing female representation in recipients of new S&E Ph.D.s has been part of a broader movement toward greater female participation in the workforce and in skilled occupations, in particular. Freeman interprets the recent influx of women into science and engineering occupations as a one-time, permanent correction to their previously low representation.[7] The huge increase in enrollments of foreign-born students in U.S. science and engineering graduate programs has been attributed to three factors: (1) extension of opportunities for higher education in highly populated, less-developed countries such as China and India (to be discussed further in Section 2.4); (2) the predominance of U.S. universities among suppliers of high-quality graduate education; and (3) features of U.S. immigration policy which give preference to H-1B visa applicants who have recently received a graduate degree from a U.S. institution.[8]

Reasons for the decline in the number of U.S.-born males entering U.S. science and engineering graduate programs have been hotly debated. Of particular interest is the question of whether foreign students have crowded out the native-born from U.S. graduate programs, or whether interest among native-born males in pursuing a Ph.D. has diminished of its own accord. As noted by Borjas, the strong negative correlation between enrollments of native-born men and foreign students in U.S. graduate programs is consistent with both the "crowding out" hypothesis and the alternative hypothesis that, when faced with declining applications from native-born males, graduate programs have admitted more foreign students in an effort to maintain program size.[9] Supporting the second hypothesis is evidence from an analysis of graduate admissions that schools give a substantial preference to U.S. citizens over foreign applicants. Education statistics also indicate that the rising number of foreign-born students have largely been placed in lower-ranked programs which have expanded to meet the growing demand for graduate education.[10]

Freeman and others have argued that native-born males are simply responding to financial incentives, citing statistics showing that the financial rewards to getting Ph.D.s in science and engineering fields have fallen relative to the rewards available in professional fields such as medicine, law, business and finance.[11] Of course, some of the relative decline in earnings of S&E doctorates may be attributable to the influx of foreign-born workers with advanced degrees. Borjas has estimated that an immigration-induced increase in the supply of doctorates lowers the wage of

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[7] See R. Freeman, E. Jin and C. Shen, "Where Do New U.S.-Trained Science and Engineering PhDs Come From?" in P. Stephan and R. Ehrenberg (eds.) *Science and the University*, University of Wisconsin Press, 2007.

[8] See R. Freeman and D. Goroff, "Introduction" in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment,* The University of Chicago Press, 2009.

[9] See G. Borjas, "Do Foreign Students Crowd Out Native Students from Graduate Programs?" in P. Stephan and R. Ehrenberg (eds.) *Science and the University*, University of Wisconsin Press, 2007.

[10] See R. Freeman and D. Goroff, "Introduction" in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment,* The University of Chicago Press, 2009.

[11] See W. Butz, G. Bloom, et al., "Is There a Shortage of Scientists and Engineers? How Would We Know?" Rand Corporation, IP-241, 2003. See also R. Freeman, "Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership?" in A. Jaffee, J. Lerner and S. Stern (eds.) *Innovation Policy and the Economy Vol. 6,* National Bureau of Economic Research, MIT Press, 2006. See also R. Freeman, E. Jin and C. Shen, "Where Do New U.S.-Trained Science and Engineering PhDs Come From?" in P. Stephan and R. Ehrenberg (eds.) *Science and the University,* University of Wisconsin Press, 2007.

competing workers by 3 to 4 percent.[12] He concludes that the influx of foreign students into U.S. graduate programs has indeed harmed the economic opportunities of competing native workers.

It is also possible that the propensity for native-born men to attend graduate school has declined for reasons other than diminished financial rewards or crowding out by foreign students. Native-born men may simply no longer wish to pursue careers that require graduate degrees in science or engineering, whether because of a discomfort with the rigorous mathematical requirements in these fields or a preference for other kinds of work.

Exhibit 2.9 provides a snapshot for 2006 of all U.S. employed individuals who, at one time or another, had received a science or engineering Ph.D. from a U.S. university. The data are displayed by field of study, sex and country of birth. Among the fields listed, those with the highest representation of women are the social sciences (36 percent) and life sciences (33 percent). Women still account for only 10 percent of workers with an engineering Ph.D. Foreign-born workers with U.S. doctorate degrees are most prevalent in the fields of computer science and engineering. Over 45 percent of workers with U.S. Ph.D.s in these fields were born outside of the United States. Asians figure most prominently among foreign-born workers with U.S. science and engineering Ph.D.s – accounting for 79 percent of all foreign-born doctorate recipients in engineering, 70 percent of the foreign-born in computer science and 66 percent of all foreign-born with Ph.D.s in life or physical sciences. A summary of foreign recipients of U.S. S&E doctorate degrees awarded from 1987-2007 shows the top four countries of origin to be China (with 24 percent of the total), India (10 percent), South Korea (10 percent) and Taiwan (9 percent).

### Exhibit 2.9: Employed Doctoral Scientists and Engineers by Field of Study, Gender and Place of Birth, 2006

| | Computer Sciences | Mathematics & Statistics | Engineering | Life Sciences | Physical Sciences | Social Sciences |
|---|---|---|---|---|---|---|
| **Total number** | 13,580 | 29,170 | 106,520 | 155,990 | 113,330 | 80,220 |
| **Sex** | | | | | | |
| % male | 82.8% | 82.5 | 90.2 | 67.1 | 83.5 | 64.3 |
| % female | 17.2% | 17.5 | 9.8 | 32.9 | 16.5 | 35.7 |
| **Place of birth** | | | | | | |
| United States | 53.4% | 64.7 | 52.2 | 77.1 | 73.3 | 80.9 |
| Foreign born | 46.6% | 35.3 | 47.8 | 22.9 | 26.7 | 19.1 |
| Asia | 32.8% | 21.3 | 37.5 | 15.1 | 17.6 | 8.7 |
| Europe | 7.9% | 8.5 | 4.7 | 3.7 | 5.5 | 4.6 |
| Other | 5.9% | 5.5 | 5.6 | 4.1 | 3.6 | 5.8 |

***Source:*** *NSF, Survey of Doctorate Recipients*

## 2.3 Earnings of Scientists and Engineers

In addition to the level of employment, wages are a variable of primary interest in an analysis of labor markets. For workers, wages are a principal determinant of standard of living, and they

[12] See G. Borjas, "Immigration in High-Skill Labor Markets: The Impact of Foreign Students on the Earnings of Doctorates," in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment*, The University of Chicago Press, 2009.

measure the benefits of investing in or entering a particular occupation. For employers, wages represent a cost and are critical in determining whether it is profitable to undertake a productive activity in given market area. From an economist's perspective, wages serve the function of adjusting to redress any imbalance between the demand for workers with a particular skill and the supply of workers with that skill. Labor shortages, for example, give rise to and become evident through a large increase in the wages earned in those occupations.

### 2.3.1 Historical Trends

Espenshade and others have used data on earnings from the 1970 and 1990 decennial censuses and the 1997 Current Population Survey to assess trends in earnings of U.S. scientists and engineers from 1970-1997.[13] After adjusting for inflation and shifts in the sex and foreign-born composition of the S&E workforce, they find that the real earnings of scientists and engineers rose by 12.7 percent from 1970-1990. Then from 1990-1997, real earnings fell by 3.8 percent. The decline in real earnings coincided with a period in which U.S. immigration policy was relaxed to allow for large inflows of foreign-born technical workers. For the entire period, 1970-1997, real annual earnings of individual S&E workers increased 8.4 percent, or at the modest rate of 0.3 percent per year.

Data from the BLS Occupational Employment and Wage Survey provide highly detailed information on more recent movements in the wages of specific occupational groups. Exhibit 2.10 shows movements in wages from 2000-2010 of all U.S. workers (excluding the self-employed), organized into 22 broad occupational categories. The data are for wages and salaries only and do not include benefits or other forms of employee compensation. The data are not adjusted for inflation.

### Exhibit 2.10: Growth in U.S. Wages by Major Occupational Group, 2000-2010

| Occ Code | Occ Title | Mean Annual U.S. Wages 2010 | Mean Annual U.S. Wages 2000 | Percent Change |
|---|---|---|---|---|
| 00-0000 | All Occupations | $44,410 | $32,890 | 35.0% |
| 11-0000 | Management Occupations | 105,440 | 68,190 | 54.6 |
| 29-0000 | Healthcare Practitioners and Technical Occupations | 71,280 | 47,990 | 48.5 |
| 23-0000 | Legal Occupations | 96,940 | 68,930 | 40.6 |
| 17-0000 | Architecture and Engineering Occupations | 75,550 | 54,060 | 39.8 |
| 13-0000 | Business and Financial Operations Occupations | 67,690 | 48,470 | 39.7 |
| 19-0000 | Life, Physical, and Social Science Occupations | 66,390 | 47,790 | 38.9 |
| 33-0000 | Protective Service Occupations | 42,490 | 30,780 | 38.0 |
| 27-0000 | Arts, Design, Entertainment, Sports, and Media Occupations | 52,290 | 38,640 | 35.3 |
| 25-0000 | Education, Training, and Library | 50,440 | 37,900 | 33.1 |

[13] See T. Espenshade, M. Usdansky and C. Chung, "Employment and Earnings of Foreign-Born Scientists and Engineers," *Population Research and Policy Review*, April 2001, pp.81-105.

| | | | | |
|---|---|---|---|---|
| | Occupations | | | |
| 15-0000 | Computer and Mathematical Occupations | 77,230 | 58,050 | 33.0 |
| 35-0000 | Food Preparation and Serving Related Occupations | 21,240 | 16,070 | 32.2 |
| 41-0000 | Sales and Related Occupations | 36,790 | 27,990 | 31.4 |
| 21-0000 | Community and Social Service Occupations | 43,180 | 32,910 | 31.2 |
| 37-0000 | Building and Grounds Cleaning and Maintenance Occupations | 25,300 | 19,570 | 29.3 |
| 45-0000 | Farming, Fishing, and Forestry Occupations | 24,330 | 18,860 | 29.0 |
| 31-0000 | Healthcare Support Occupations | 26,920 | 21,040 | 27.9 |
| 51-0000 | Production Occupations | 33,770 | 26,450 | 27.7 |
| 53-0000 | Transportation and Material Moving Occupations | 32,660 | 25,630 | 27.4 |
| 47-0000 | Construction and Extraction Occupations | 43,870 | 34,440 | 27.4 |
| 43-0000 | Office and Administrative Support Occupations | 33,470 | 26,300 | 27.3 |
| 49-0000 | Installation, Maintenance, and Repair Occupations | 42,810 | 33,760 | 26.8 |
| 39-0000 | Personal Care and Service Occupations | 24,590 | 20,510 | 19.9 |

***Source:*** *BLS, Occupational Employment Statistics*

Overall, mean annual wages of U.S. workers increased by 35 percent from 2000-2010. This compares with a rise of 26 percent in the cost of living, as measured by the CPI for all urban wage earners. The occupational categories in Exhibit 2.10 are ordered by the percentage growth in wages over the period. Occupations registering the fastest wage growth were management (55 percent) and health care (49 percent). Lawyers and workers in legal occupations were the third-fastest category with wage growth of 41 percent. Turning to the science and engineering occupations, architects and engineers registered wage growth of 40 percent, which was fourth-fastest among the 22 occupational categories. Wage increases for individuals in life, physical and social science occupations were sixth-fastest at 39 percent. Workers in computer-related occupations had average wage increases of 33 percent, which was tenth-fastest but slightly below the national average.

In broad summary, data from BLS surveys indicate that recent wage increases in science and engineering occupations have been faster than the rate of inflation and above or near the average across all occupations in the economy. However, S&E wages have risen at a considerably slower pace than wages earned by people in management positions and health care practitioners. Among S&E workers, architects and engineers have experienced the fastest wage growth. But wage growth of a similar magnitude has also been recorded in other skilled occupations, including law and business and financial operations.

Exhibit 2.11 provides information on recent wage growth for highly detailed occupational categories. Detailed breakdowns are given for each of the three major science and engineering groups, along with details for other occupation groups that registered rapid wage growth.

### Exhibit 2.11: Growth in U.S. Wages for Selected Detailed Occupations, 2000-2010

| Occ Code | Occ Title | Employment 2010 | Mean Annual U.S. Wages 2010 | Mean Annual U.S. Wages 2000 | Percent Change in Wages |
|---|---|---|---|---|---|
| **00-0000** | **All Occupations** | **127,097,160** | **$44,410** | **$32,890** | **35.0%** |
| 11-0000 | **Management Occupations** | **6,022,860** | **105,440** | **68,190** | **54.6** |
| 11-1011 | Chief Executives | 273,500 | 173,350 | 104,630 | 65.7 |
| 11-3031 | Financial Managers | 478,940 | 116,970 | 72,570 | 61.2 |
| 11-1021 | General and Operations Managers | 1,708,080 | 113,100 | 70,220 | 61.1 |
| 11-2022 | Sales Managers | 319,300 | 114,110 | 74,230 | 53.7 |
| 11-3021 | Computer and Information Systems Managers | 288,660 | 123,280 | 80,250 | 53.6 |
| 11-9111 | Medical and Health Services Managers | 282,990 | 93,670 | 61,640 | 52.0 |
| 11-9033 | Education Administrators, Postsecondary | 110,360 | 96,680 | 64,770 | 49.3 |
| 11-9041 | Architectural and Engineering Managers | 174,720 | 125,900 | 85,450 | 47.3 |
| 11-9032 | Education Administrators, Elementary and Secondary School | 222,270 | 89,990 | 68,940 | 30.5 |
| 29-0000 | **Healthcare Practitioners and Technical Occupations** | **7,346,580** | **71,280** | **47,990** | **48.5** |
| 29-1067 | Surgeons | 43,230 | 225,390 | 137,400 | 64.0 |
| 29-1062 | Family and General Practitioners | 97,820 | 173,860 | 107,780 | 61.3 |
| 29-1051 | Pharmacists | 268,030 | 109,380 | 69,440 | 57.5 |
| 29-2037 | Radiologic Technologists and Technicians | 216,730 | 55,730 | 37,290 | 49.5 |
| 29-1111 | Registered Nurses | 2,655,020 | 67,720 | 46,410 | 45.9 |
| 29-1020 | Dentists | 98,610 | 164,111 | 112,820 | 45.5 |
| 29-2011 | Medical and Clinical Laboratory Technologists | 164,430 | 56,870 | 41,260 | 37.8 |
| 29-2052 | Pharmacy Technicians | 333,500 | 29,330 | 21,600 | 35.8 |
| 29-2041 | Emergency Medical Technicians and Paramedics | 221,760 | 33,300 | 24,740 | 34.6 |
| 29-2021 | Dental Hygienists | 177,520 | 68,680 | 51,980 | 32.1 |
| 23-0000 | **Legal Occupations** | **992,650** | **96,940** | **68,930** | **40.6** |
| 23-1011 | Lawyers | 561,350 | 129,440 | 91,320 | 41.7 |
| 23-2011 | Paralegals and Legal Assistants | 247,940 | 49,640 | 38,790 | 28.0 |
| 17-0000 | **Architecture and Engineering Occupations** | **2,305,530** | **75,550** | **54,060** | **39.8** |
| 17-2171 | Petroleum Engineers | 28,210 | 127,970 | 79,910 | 60.1 |

| | | | | | |
|---|---|---|---|---|---|
| 17-2061 | Computer Hardware Engineers | 66,960 | 101,600 | 70,100 | 44.9 |
| 17-2011 | Aerospace Engineers | 78,450 | 99,000 | 69,040 | 43.4 |
| 17-2131 | Materials Engineers | 21,830 | 85,860 | 60,420 | 42.1 |
| 17-2051 | Civil Engineers | 249,120 | 82,280 | 58,380 | 40.9 |
| 17-2041 | Chemical Engineers | 28,720 | 94,590 | 67,160 | 40.8 |
| 17-1011 | Architects, Except Landscape and Naval | 87,700 | 78,530 | 56,020 | 40.2 |
| 17-2072 | Electronics Engineers, Except Computer | 133,660 | 92,730 | 66,490 | 39.5 |
| 17-3012 | Electrical and Electronics Drafters | 27,960 | 55,960 | 40,420 | 38.4 |
| 17-3023 | Electrical and Electronics Engineering Technicians | 147,750 | 56,690 | 41,210 | 37.6 |
| 17-2141 | Mechanical Engineers | 234,400 | 82,480 | 60,860 | 35.5 |
| 17-2071 | Electrical Engineers | 148,770 | 87,770 | 66,320 | 32.3 |
| 17-2112 | Industrial Engineers | 202,990 | 78,450 | 59,900 | 31.0 |
| 17-2161 | Nuclear Engineers | 18,610 | 101,500 | 78,770 | 28.9 |
| 17-3013 | Mechanical Drafters | 64,440 | 51,200 | 40,330 | 27.0 |
| 17-3027 | Mechanical Engineering Technicians | 44,170 | 51,450 | 41,460 | 24.1 |
| 17-3026 | Industrial Engineering Technicians | 61,630 | 50,540 | 44,330 | 14.0 |
| 13-0000 | **Business and Financial Operations Occupations** | **6,090,910** | **67,690** | **48,470** | **39.7** |
| 13-1111 | Management Analysts | 536,310 | 87,260 | 60,350 | 44.6 |
| 13-2051 | Financial Analysts | 220,810 | 86,040 | 59,760 | 44.0 |
| 13-2011 | Accountants and Auditors | 1,072,490 | 68,960 | 48,090 | 43.4 |
| 13-2072 | Loan Officers | 283,330 | 65,900 | 47,760 | 38.0 |
| 13-1031 | Claims Adjusters, Examiners, and Investigators | 262,540 | 60,200 | 44,000 | 36.8 |
| 13-1023 | Purchasing Agents, Except Wholesale, Retail, and Farm Products | 272,370 | 60,160 | 44,160 | 36.2 |
| 13-2052 | Personal Financial Advisors | 155,360 | 91,220 | 67,430 | 35.3 |
| 19-0000 | **Life, Physical, and Social Science Occupations** | **1,064,510** | **66,390** | **47,790** | **38.9** |
| 19-1021 | Biochemists and Biophysicists | 22,800 | 86,580 | 59,070 | 46.6 |
| 19-2032 | Materials Scientists | 8,390 | 86,300 | 62,980 | 37.0 |
| 19-1042 | Medical Scientists, Except Epidemiologists | 93,560 | 86,710 | 63,430 | 36.7 |
| 19-1022 | Microbiologists | 18,330 | 72,030 | 53,040 | 35.8 |
| 19-2012 | Physicists | 16,860 | 112,020 | 82,990 | 35.0 |
| 19-2031 | Chemists | 80,180 | 73,240 | 54,280 | 34.9 |
| 19-4021 | Biological Technicians | 72,940 | 41,740 | 32,970 | 26.6 |
| 19-4031 | Chemical Technicians | 59,440 | 44,200 | 37,080 | 19.2 |
| 15-0000 | **Computer and Mathematical Occupations** | **3,283,950** | **77,230** | **58,050** | **33.0** |

| | | | | | |
|---|---|---|---|---|---|
| 15-1133 | Software Developers, Systems Software | 378,920 | 97,960 | 70,890 | 38.2 |
| 15-1141 | Database Administrators | 104,080 | 75,730 | 55,810 | 35.7 |
| 15-1142 | Network and Computer Systems Administrators | 333,210 | 72,200 | 53,690 | 34.5 |
| 15-2031 | Operations Research Analysts | 62,210 | 76,980 | 57,700 | 33.4 |
| 15-1121 | Computer Systems Analysts | 495,800 | 81,250 | 61,210 | 32.7 |
| 15-1132 | Software Developers, Applications | 499,280 | 90,410 | 70,300 | 28.6 |
| 15-1150 | Computer Support Specialists | 579,270 | 49,930 | 39,680 | 25.8 |
| 15-1131 | Computer Programmers | 333,620 | 74,900 | 60,970 | 22.8 |

***Source:*** *BLS, Occupational Employment Statistics*

The data reveal a tendency within each major category for occupations requiring the greatest skills and highest levels of education to experience the largest percentage wage increases. So financial managers have received larger wage increases than administrators of elementary and secondary schools; earnings of medical doctors and pharmacists have risen faster than the wages of nurses who, in turn, have received larger wage increases than laboratory technologists and dental hygienists; incomes of lawyers have grown faster than wages of paralegals, etc. The data support the widely communicated thesis that the premium to skills and education in the United States has been rising. Since science and engineering occupations require above-average levels of training and education, it is not surprising that earnings growth in these occupations has generally exceeded the economy-wide average.

There is considerable variation in wage growth within each broad science and engineering category. Looking first at architects and engineers, the largest percentage increase in earnings was received by petroleum engineers. This was undoubtedly a consequence of the huge run-up in oil prices during the middle part of the decade. Other occupations recording pay increases at a rate that was above average for this category include computer hardware engineers, aerospace engineers and materials engineers. Workers in occupations related to electrical, mechanical and industrial engineering generally experienced wage increases at or below the average rate. Drafters and technicians in these fields received particularly small pay increases.

Within the science occupations, biochemists and biophysicists received unusually large wage increases. Most other scientists, including medical scientists, chemists, microbiologists and physicists registered wage increases at about the economy-wide average. Science technicians received the smallest percentage wage increases.

On average, workers in computer-related occupations recorded wage increases that were slightly below the average for the economy. Occupations recording the largest wage gains were developers of system software and database and network administrators. Workers receiving the smallest wage increases were computer programmers and computer support specialists. Competitive pressures from foreign outsourcing played a role in holding down pay increases for computer programmers.

### 2.3.2 Comparing Earnings of Highly Educated Workers

As noted in Section 2.2.4, workers with Ph.D.s are especially critical for advanced research. Exhibit 2.12 provides comparative statistics for 1990 and 2000 on the earnings experiences of U.S. workers with various advanced degrees. The data are from the decennial census. Among workers with advanced S&E degrees, those with Ph.D.s in math and engineering earn significantly more than do those with Ph.D.s in the life, physical or social sciences. In 2000, for example, engineers with doctorate degrees earned 45 percent more than did workers with Ph.D.s in the life sciences and 25 percent more than those in the physical sciences. Even highly compensated, doctorate-level engineers, however, earn considerably less than workers with advanced professional degrees. Medical doctors earn 72 percent and lawyers 26 percent more than do engineers with a doctorate degree. These statistics indicate that for students deciding on a career requiring advanced education, there have been significantly higher financial rewards to entering a professional occupation than a science or engineering occupation.

### Exhibit 2.12: Income Growth of U.S. Individuals with Advanced Degrees, 1990-2000

| Degree | 1990 | 2000 | Percent Change |
|---|---|---|---|
| Ph.D. | | | |
| Mathematics | $58,300 | $86,600 | 48.5% |
| Engineering | 64,600 | 91,100 | 41.0 |
| Life science | 45,600 | 62,700 | 37.5 |
| Physical science | 56,300 | 73,000 | 29.7 |
| Social science | 54,200 | 74,600 | 37.6 |
| MD | 98,800 | 156,400 | 58.3 |
| Lawyer | 76,900 | 114,700 | 49.2 |
| College grads, 4 years only | 30,800 | 46,900 | 52.3 |

***Source:*** *R. Freeman, using IPUMS data from the 1990 and 2000 decennial censuses*[14]

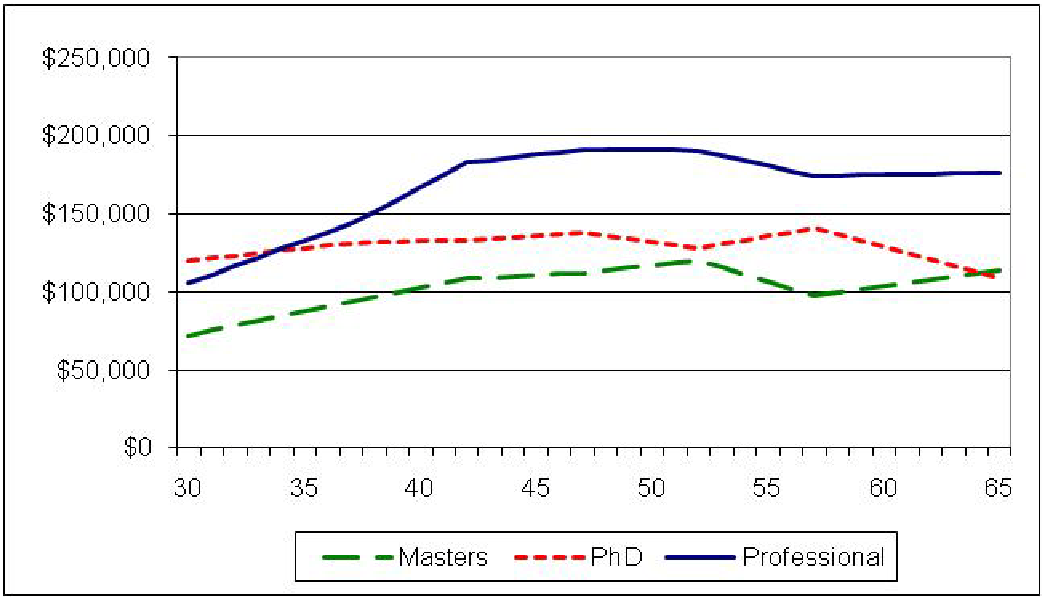
Exhibit 2.12 also indicates that the returns to investing in an advanced science or engineering degree have been falling relative to the returns available in other fields requiring long periods of education. From 1990-2000, the mean earnings of doctorate-level engineers rose 41 percent and the earnings of workers with Ph.D.s in the life or social sciences rose 38 percent. These are significantly slower rates of increase in earnings than those realized by MDs (58 percent) and lawyers (49 percent). Earnings of S&E doctorate-level workers, in fact, grew more slowly than the average earnings of workers with a bachelor's degree (52 percent). Changes in relative financial rewards certainly must have been a factor in the declining propensity of U.S.-born men to pursue advanced degrees in science and engineering.

Exhibit 2.13 provides more current evidence of relatively poor earnings experiences of Ph.D.-level scientists and engineers. The chart uses data from the 2008 Current Population Survey to construct a life-cycle path of earnings for male workers with advanced degrees. Because of data limitations, the series for workers with Ph.D.s includes all workers with doctorates, not simply those with science and engineering Ph.D.s. The series for workers with professional degrees includes workers with advanced degrees in medicine, law and business administration. The data suggest that over a working life measured from age 30 to age 65, men with advanced professional degrees can expect to earn $1.4 million more than the average Ph.D. holder. If earnings differentials are discounted to age

[14] R. Freeman, "Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership?" in A. Jaffee, J. Lerner and S. Stern (eds.) *Innovation Policy and the Economy Vol. 6, National Bureau of Economic Research*, MIT Press, 2006, Exhibit 3.

30 using a discount rate of 3 percent, the lifetime earnings advantage of men with professional degrees is more than $700 thousand.

### Exhibit 2.13: Mean Earnings of Men with Advanced Degrees, 2008




***Note:*** *Full-time, year-round workers*
***Source:*** *U.S. Census Bureau, Current Population Survey, 2009 Annual Social and Economic Supplement*

### 2.3.3 Is There a Shortage of Scientists and Engineers?

In the mid 2000s, policymakers began to express concern about the U.S. job market for scientists and engineers at a level not seen since the 1950s following the Soviet Union's launch of Sputnik. National commissions and professional associations issued reports sounding an alarm about the dangers of declining U.S. leadership in science and engineering and its implications for the country's national security and international competitiveness. Most prominent was a report from the National Academy of Sciences entitled *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. The report calls for new policies to increase the supply of scientists and engineers by improving math and science education in grades K-12, increasing federal government investment in basic research and providing more financial support for students in U.S. science and engineering graduate programs.[15]

Claims of shortages of science and engineering workers have been a recurring theme over the past several decades. One of the most notable occurred in the late 1980s when leaders of the National Science Foundation announced that the United States faced an impending shortage of 675,000 scientists and engineers. The projections proved to be based on highly implausible scenarios in the labor market. When the scientific community learned what had happened, angry articles and

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[15] Committee on Prospering in the Global Economy of the 21st Century (U.S.), Committee on Science, Engineering and Public Policy (U.S.) *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, National Academies Press, 2007.

editorials were published in science journals, and the new director of the NSF apologized.[16] Michael Teitelbaum, Eric Weinstein, and others have argued that these recurring alarms about shortages of scientists and engineers are being sounded on behalf of high-tech companies and major universities who stand to profit from policies that lower the cost of S&E labor and increase federal funding for basic research and graduate study.[17]

In the minds of economists, market shortages are self-correcting and temporary. If at going wages, businesses want to hire more scientists and engineers than are available and willing to work, then competition between employers will force wages up. This process will serve to eliminate the shortage by reducing the number of positions businesses seek to fill and increasing the number of workers available. Statistical evidence such as that presented here clearly indicates that U.S. wages and salaries of scientists and engineers have lagged behind those in other occupations requiring a high level of training and education. If rapidly rising pay is the primary indicator of a labor shortage, then the country faces much more acute shortages of business executives and managers, doctors and pharmacists, lawyers and financiers. Scientific careers have become much less financially attractive in the 1990s and 2000s relative to what they were in the 1960s and 1970s.

Instead of dismissing continued claims of labor shortages as self-serving or disingenuous, Freeman suggests that it is more reasonable and accurate to say that the U.S. has an adequate supply of scientists and engineers, but only because of a sizeable influx of foreign-born students and technical workers.[18] The U.S. is not experiencing a shortage of scientists and engineers but of native-born entrants into these fields. The question is whether anything should be done about it. For young Americans to choose careers in science and engineering rather than medicine, law or finance, wages in S&E occupations must rise significantly. But if they do, many of these jobs will go overseas.

## 2.4 The Long-Term Outlook

### 2.4.1 International Competition

The most important factor that will shape the future U.S. market for S&E workers is the rapid increase in science and engineering capabilities in other countries of the world. Global developments, especially trends toward mass higher education in highly populated, low-income countries, are eroding U.S. dominance of science and technology. This is an inexorable process. The United States with only 5 percent of the world's population cannot continue to account for 35-45 percent of science and engineering activity, as it did at the end of twentieth century. The question is

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[16] See R. Freeman and D. Goroff, "Introduction" in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment,* The University of Chicago Press, 2009.

[17] See E. Weinstein, "How and Why Government, Universities and Industry Create Domestic Labor Shortages of Scientists and High-Tech Workers," http://www.nber.org/~peat/PapersFolder/Papers/SG/NSF.html See also M. Teitelbaum, "Do We Need More Scientists?" in T. Kelly, W. Butz, et al. (eds.) *The U.S. Scientific and Technical Workforce: Improving Data for Decisionmaking*, Rand Corporation, June 2004.

[18] See R. Freeman, "Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership?" in A. Jaffee, J. Lerner and S. Stern (eds.) *Innovation Policy and the Economy Vol. 6*, National Bureau of Economic Research, MIT Press, 2006.

how the United States will manage the transition from being a superpower in science and engineering to one of many centers of excellence.[19]

The erosion of U.S. leadership in science and engineering is evident across a broad spectrum of metrics. As measured by research output, the U.S. share of papers and citations in science journals is falling, as is the U.S. share of world R&D expenditures. As measured by numbers of scientists and engineers, U.S. shares of both S&E graduates and workers are falling. On a more familiar level, the effects of a global catch-up in science and engineering expertise are apparent in the rising share of foreign students in U.S. graduate programs, a worsening job market for U.S. S&E graduates, the outsourcing of IT jobs to India, and increasing R&D investment by U.S. multinationals in China, India, the U.K. and Germany.

Historians give many reasons for how the United States came to dominate world science and technology during the second half of the twentieth century: the flight of high-level European scientists from the Nazis; the slow post-WWII recovery of higher education in Europe; the rapid expansion of mass college education in the U.S. during the 1950s and 1960s; U.S. government support of R&D and graduate education; a focus in Soviet science and engineering on military technology; and the retarding effects of the cultural revolution on education in China.[20] But the factors that gave the U.S. its leadership position in science and technology were exceptional and fleeting. The world is catching up. Europe has rebuilt and expanded its university system. More importantly, countries with huge populations such as China and India have made higher education in general, and science and engineering education in particular, a priority in their agendas for economic development.

Exhibit 2.14 shows trends in higher education enrollments for selected countries and country groups. In 1970 the United States accounted for 8.5 million or 29 percent of world enrollments in higher education. All other advanced countries combined had 4.9 million people in higher education. China and India, with their large populations, had only .1 million and 2.5 million people, respectively, enrolled in higher education. From 1970 to 2000, there was a surge in tertiary education around the world. U.S. enrollments increased by 55 percent to 13.2 million. But the number enrolled in other advanced countries rose fourfold to 19.4 million. The number enrolled in developing countries increased by a little more than fourfold to 66.9 million. The U.S. share of world tertiary education enrollments fell from 29 percent to 13 percent. The share accounted for by developing countries rose from 54 percent to 67 percent.

## Exhibit 2.14: World Enrollments in Higher Education (In Millions)

| | 1970 | 1980 | 1990 | 2000 | 2009 |
|---|---|---|---|---|---|
| World | 29.4 | 55.3 | 67.6 | 99.5 | 164.6 |
| United States | 8.5 | 12.1 | 13.7 | 13.2 | 19.1 |

[19] See R. Freeman, "Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership?" in A. Jaffee, J. Lerner and S. Stern (eds.) *Innovation Policy and the Economy Vol. 6*, National Bureau of Economic Research, MIT Press, 2006.

[20] See R. Freeman, "Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership?" in A. Jaffee, J. Lerner and S. Stern (eds.) *Innovation Policy and the Economy Vol. 6*, National Bureau of Economic Research, MIT Press, 2006.

| | | | | | |
|---|---|---|---|---|---|
| Other advanced countries | 4.9 | 8.2 | 12.9 | 19.4 | 18.9 |
| Developing countries | 16.0 | 35.0 | 41.0 | 66.9 | 126.6 |
| China | 0.1 | 1.7 | 3.8 | 7.4 | 29.3 |
| India | 2.5 | 3.5 | 5.0 | 9.4 | 14.9 |
| U.S. share of world total | 28.9% | 21.9% | 20.3% | 13.3% | 11.6% |

***Source:*** *UNESCO, Institute for Statistics, online files*

Since 2000, U.S. enrollments in higher education have increased by 45 percent to 19.1 million (using the most recent figures for 2009). At the same time, higher education in developing countries has exploded. Tertiary education enrollments in developing countries are estimated to have increased from 66.9 million in 2000 to 126.6 million in 2009. The less developed world now accounts for 77 percent of the world's population of students enrolled in institutions of higher education. In China alone the number enrolled in tertiary education has increased from 7.4 million to 29.3 million, which is 53 percent larger than U.S. enrollments. The United States now accounts for 12 percent of world enrollments in higher education.

Exhibit 2.15 provides information for selected countries on numbers of science and engineering degrees awarded in 2005. To help understand the reasons for country differences in degree production, the table expresses the total number of S&E degrees awarded in a country as the product of the country's population of 24-year olds, the propensity for individuals in that age group to obtain a higher education degree and the percent of all degrees that are in science and engineering fields. This breakdown allows us to separate out the roles played by population size, general rates of higher education attainment and emphasis on science and engineering within systems of higher education.

### Exhibit 2.15: International Production of S&E Degrees, 2005

| | **Total S&E degrees** (1) | **Population of 24-yr olds** (2) | **Total degrees per 1,000 of 24-yr olds** (3) | **S&E degrees as percent of all degrees** (4) |
|---|---|---|---|---|
| China | 796,430 | 18,562,000 | 79 | 54 |
| France | 94,605 | 764,000 | 358 | 35 |
| Germany | 74,970 | 955,000 | 207 | 38 |
| Japan | 349,015 | 1,580,000 | 349 | 63 |
| S. Korea | 117,921 | 765,000 | 351 | 44 |
| United Kingdom | 112,500 | 753,000 | 407 | 37 |
| United States | 470,214 | 4,069,200 | 358 | 32 |

***Note:*** *Col.(1) equals Col.(2)*Col.(3)*Col.(4)/(1000*100)*
***Source:*** *NSF, Science and Engineering Indicators 2010*

China is the leading producer of S&E degrees by virtue of its size. China still is far behind the developed countries in rate of degree attainment in the general population. Programs of higher education in China do provide greater emphasis on science and engineering than is the case in Western countries. But it is the absolute size of its population that enables China to produce 69 percent more S&E degrees than the U.S. Japan places an even greater emphasis on science and engineering in its schools. This enables Japan to produce 74 percent as many S&E degrees as the United States even though its young adult population is only 39 percent as large. Compared with other developed Western countries, the United States has a similar normalized rate of degree attainment and places only slightly less emphasis on science and engineering in degrees attained. But the relatively large size of the U.S. population allows the country to place second in the table in S&E degree production.

Countries around the world are also closing the gap with the United States in production of doctorate degrees. The quality of graduate programs in most foreign countries is still well below that of U.S. programs. But in time, quality differentials will narrow. Exhibit 2.16 shows how, in terms of number of degrees, the United States is now just one of many regions producing a large number of S&E doctorate degrees. Based on doctoral degrees awarded from 2002-06, the eight W. European countries in the table collectively produced 38 percent more S&E Ph.D.s than the U.S. The five Asian countries listed together produced 29 percent more doctorate degrees.

### Exhibit 2.16: Science and Engineering Ph.D.s Awarded at Universities in Selected Countries

| | **Doctoral degrees awarded from 2002-06** |
|---|---:|
| United States | 135,265 |
| China | 77,167 |
| Germany | 50,430 |
| United Kingdom | 45,631 |
| Japan | 38,734 |
| India | 34,555 |
| France | 31,294 |
| Italy | 19,045 |
| South Korea | 17,380 |
| Spain | 17,013 |
| Sweden | 10,446 |
| Switzerland | 6,961 |
| Taiwan | 6,452 |
| Austria | 5,415 |

***Source:*** *NSF, Science and Engineering Indicators 2010, Appendix tables 2-40 and 2-41*

### 2.4.2 Implications for the U.S. Economy

From a world perspective, the rise in educational attainment and the attendant growth in science and engineering expertise in foreign countries is unequivocally a good thing. Increased numbers of S&E workers will stimulate the growth of technical knowledge, leading to improvements in productivity and the development of new products and processes. With many more science and engineering researchers working in labs around the world, and the Internet to help coordinate that research and spread ideas and findings, the world may indeed be poised to enter a new golden age of technological progress.

In the long run, the primary beneficiaries of technological advance are consumers of new and cheaper products, not their producers. As consumers, Americans stand to benefit greatly from advances in biotechnology, nanotechnology or fuel cell technology whether those advances are made by US.-born workers or foreign-born workers, by people working in the U.S. or in another country. The downside to technical advance in foreign countries, of course, is that the U.S. will suffer an erosion of its comparative advantage in the development and manufacture of high-tech goods. Owners of U.S. high-tech firms and their workers have enjoyed monopoly rents derived from early leadership in the technologies developed over the past sixty years. These rents will be competed away. In the long run, the spread of technology to the rest of the world and the increasing contribution of foreign countries to world innovation are certain to outweigh the costs associated with a loss of U.S. hegemony in science and technology. But U.S. adjustment to increasing competition from countries such as China and India is likely to be far more stressful than what the country endured when Europe and Japan recovered after WWII.[21]

What U.S. policies would best minimize these adjustment costs? Proposals to internally strengthen U.S. capabilities in science and engineering, such as education reforms aimed at improving students' STEM skills, could be productive, especially if they are part of an overall effort to increase efficiency in the public school system rather than a plan supported with resources taken from other areas of education. But the policy arena that is most critical in determining the path of U.S. adjustment is immigration. The major policy issue is whether it is better to attract more foreign students and technical workers or force U.S. multinationals to try and maintain their competitiveness by off-shoring an increasing amount of high-tech production and research.[22]

Continued or expanded immigration preferences for foreign-born students plays to the competitive advantage the United States enjoys in university education, especially graduate-level education. The strong reputation of U.S. universities is evidenced, for example, in the rankings of The Institute for Higher Education at Shanghai Jiao Tong University. In these rankings, American universities occupy eight of the top ten spots, nine of the next ten, and 37 out of the top 50. Economic geographers have found that proximity to a highly rated university is an important determinant in the location of corporate R&D facilities. So the strengthening of research universities through liberal immigration policies would help the country retain high-tech research and production. To reduce the risk that foreign students might return to their country of origin, immigration policies could be revised to allow students to quickly receive permanent residence or citizenship status. To avoid further discouraging U.S.-born residents from entering highly skilled S&E occupations, the government could provide more generous support for graduate education and research fellowships targeted specifically at U.S. citizens.

Another consideration which further supports a policy of immigration in lieu of offshoring is the local spillover of knowledge. Productivity in the domestic workforce is better served by allowing the local population to work with highly educated foreign workers instead of simply buying goods from them. Knowledge spillovers are widely acknowledged by economists as an important example of market failure in modern economies, and they provide intellectual support for public subsidy of firms and activities engaged in the creation of knowledge.

How can the U.S. best respond to the challenge posed by a growing foreign science and engineering workforce? In the opinion of Richard Freeman: "My guess is that by educating some of the best

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[21] See R. Freeman, "Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership?" in A. Jaffee, J. Lerner and S. Stern (eds.) *Innovation Policy and the Economy Vol. 6,* National Bureau of Economic Research, MIT Press, 2006.

[22] See R. Freeman, "What Does Global Expansion of Higher Education Mean for the U.S.?" NBER Working Paper No. 14962, May 2009.

students in the world, attracting some to stay in the country and positioning the U.S. as an open hub of ideas and connections for university graduates worldwide, the country will be able to maintain excellence and leadership in the 'empire of the mind' and in the economic world more so than if it views the rapid increase in graduates overseas as a competitive threat." [23]

[23] See R. Freeman, "What Does Global Expansion of Higher Education Mean for the U.S.?" NBER Working Paper No. 14962, May 2009, p. 29.

# 3 The Mobility of S&E Workers: Does Local Training Create a Larger Local Workforce?

## 3.1 Overview

Americans are some of the most geographically mobile people in the world. Americans change state of residence 10 times more often than residents of the European Union change country of residence, and more than twice as often as EU residents move between regions of the same country.[24] Educated Americans are especially mobile. Adults with a college degree move between states with 50 percent greater frequency than do those without a college degree. In view of the mobility of highly educated U.S. workers, it is fair to raise the question of whether states should worry about the output of their own universities when assessing the availability of science and engineering workers to their economies. This chapter assesses the role local universities play in determining the size of the local S&E workforce.

Section 3.2 provides information on the tendency for S&E graduates to locate out of state after graduation. Nationwide, 38 percent of students graduating with a bachelor's degree in science or engineering leave the state shortly after graduation. For newly trained Ph.D.s, 64 percent take their first jobs out of state. Even Massachusetts, a state that hires a large number of new S&E Ph.D.s, loses two-thirds of the Ph.D.s it trains and ends up importing more than half of the new Ph.D.s it hires. Given the high fixed costs involved in operating a top graduate program, it is inevitable that high-tech employers will have to look out of state to fill their needs for S&E workers with advanced and highly specialized training.

Section 3.3 presents new primary data collected especially for this report on the stay rates of graduates of Arizona's three major universities. Stay rates for Arizona's universities are generally above the national average. For those who received an undergraduate degree in a science or engineering field at some point since 2000, the percentages with a current Arizona residence are: 72 percent for graduates of Arizona State University, 66 percent for graduates of the University of Arizona and 64 percent for those graduating from Northern Arizona University. Among ASU graduates who received a master's degree or Ph.D. in an S&E field, 47 percent are still in state. Only 24 percent of U of A graduates with advanced S&E degrees have a current Arizona residence.

Section 3.4 argues that while Americans are highly mobile, there is still a "localness" to state markets for S&E workers. A much higher percentage of students take jobs and remain in the vicinity of their university than would be expected in a "flat" world where geography was unimportant. This is especially true for undergraduates. Even among newly trained S&E Ph.D.s, stay rates in major states are 4-10 times higher than one would expect in a perfectly integrated national market.

Why do many college graduates stick around and find jobs in the same city or state as their school? Students with family who were born in or attended high school in the same area as the university they attend may have a strong preference for staying. There is also evidence that the presence of a university, especially a top-rated research university, serves to attract high-tech employers, creating the jobs graduates are looking for. Industrial R&D operations are seriously constrained by the labor market for scientists and engineers, and availability of scientific labor is an important consideration in site selection for an R&D facility. It is not only the students but the faculty at top research universities that stimulate local high-tech activity. University faculty who pioneered breakthrough

[24] See European Commission, "Geographic Mobility in the European Union," April 2008.

discoveries in integrated circuitry, recombinant DNA and nanotechnology were heavily involved in the transfer of that knowledge to industry and served as magnets for new firms wishing to develop the new technology.

Does local training of scientists and engineers create a larger local S&E workforce? It is an imperfect relationship, and policymakers would be well advised not to exaggerate it. But there is clearly inertia in people's location decisions. Evidence indicates that, in the long run, the training of a large number of university graduates in a state is associated with a large number of knowledge workers settling there. This is especially true for individuals receiving undergraduate degrees in science and engineering fields.

## 3.2 The Mobility of Educated Workers

Studies of the migration behavior of Americans have consistently found educational attainment to be one of the most significant individual characteristics influencing the propensity to migrate. Higher education is associated with a large increase in the probability of residing outside of one's birth state later in life.[25] Data from the 2000 Census indicate that 8.1 percent of people 25 yrs and older had moved to a different state sometime in the previous five years. Among adults with a bachelor's degree or higher, 12.6 percent had changed state residence.

Critical to the question of how university degrees produced in an area affect the size of the college-educated population is the propensity for new graduates to stay in the area in which they were educated. Data collected in NSF surveys of college graduates indicate that only 62 percent of those graduating with a bachelor's degree in science or engineering reside in the same state as the school they graduated from shortly after graduation.[26] A much smaller percentage of those graduating with a Ph.D. remain in state.

### 3.2.1 Migration Patterns of Newly Trained Industrial S&E Ph.D.s

One particular survey administered by the NSF, the Survey of Earned Doctorates, reveals much about the migration patterns of highly educated scientists and engineers. Notable studies of data from this survey include Stephan et al. and Sumell et al.[27] The sample of graduates analyzed by these authors consists of S&E Ph.D.s who received their degree during the period 1997-1999 and accepted a position with industry upon graduation.

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[25] See R.Hernandez-Murillo, L. Ott, M. Owyang and D. Whalen, "Patterns of Interstate Migration in the United States from the Survey of Income and Program Participation," *Federal Reserve Bank of St. Louis Review,* May/June 2001, pp.169-86.

[26] See Sumell, P. Stephan and J. Adams, "The Location Decision of New Ph.D.s Working in Industry," in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment*, The University of Chicago Press, 2009. P. 263.

[27] See P. Stephan, A. Sumell, G. Black and J. Adams, "Doctoral Education and Economic Development: The Flow of New Ph.D.s to Industry," *Economic Development Quarterly*, May 2004, pp.151-67. See also Sumell, P. Stephan and J. Adams, "The Location Decision of New Ph.D.s Working in Industry," in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment,* The University of Chicago Press, 2009.

Exhibit 3.1 provides an overview of the migration patterns of this study group. The first two columns in the table indicate whether a state or region is a net exporter or a net importer of new industrial S&E Ph.D.s. The third column shows the "stay rate" – the percent of Ph.D.s trained in a region that remains in residence there after taking a job in industry. By combining this information with that in the first two columns, it is possible to determine a region's gross outflow and gross inflow of new Ph.D.s.

### Exhibit 3.1: Interregional and Interstate Migration Patterns of New Industrial S&E Ph.D.s, 1997-1999

| Region | Number of new Ph.D.s trained in the region | Number of new Ph.D.s working in the region | Percent of new Ph.D.s produced that stay in the region |
|---|---|---|---|
| New England | 958 | 885 | 43.3% |
| Massachusetts | 713 | 594 | 36.3 |
| Mid-Atlantic | 1,890 | 1,998 | 48.8 |
| New Jersey | 311 | 766 | 45.7 |
| New York | 898 | 801 | 34.2 |
| Pennsylvania | 681 | 431 | 23.9 |
| East North Central | 2,102 | 1,346 | 37.8 |
| Illinois | 611 | 441 | 29.3 |
| Indiana | 376 | 166 | 12.2 |
| Michigan | 430 | 308 | 33.0 |
| Ohio | 445 | 314 | 33.0 |
| Wisconsin | 240 | 117 | 18.8 |
| West North Central | 698 | 504 | 35.0 |
| Minnesota | 270 | 266 | 36.7 |
| South Atlantic | 1,692 | 1,195 | 42.1 |
| Florida | 271 | 173 | 34.3 |
| Georgia | 324 | 171 | 28.1 |
| Maryland | 266 | 233 | 23.7 |
| North Carolina | 321 | 197 | 28.0 |
| Virginia | 269 | 233 | 30.1 |
| East South Central | 297 | 193 | 32.7 |
| West South Central | 896 | 1,050 | 54.8 |
| Texas | 682 | 908 | 53.7 |
| Mountain | 557 | 474 | 40.9 |
| Arizona | 197 | 181 | 40.1 |
| Colorado | 196 | 154 | 37.2 |
| Pacific | 1,831 | 2,534 | 69.4 |
| California | 1,539 | 2,126 | 67.8 |

***Source:*** *A. Sumell, P. Stephan and J. Adams*[28]

[28] A. Sumell, P. Stephan and J. Adams, "The Location Decision of New Ph.D.s Working in Industry," in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment*, The University of Chicago Press, 2009, Table 8.2.

Pacific states are major net importers of new industrial S&E Ph.D.s. California is a dominant force in the national market. California is both the largest producer of Ph.D.s going to industry and the largest employer of newly minted Ph.D.s. The New England and Mid-Atlantic regions of the country train approximately the same number of industrial Ph.D.s as they hire. Of new Ph.D.s going to top 200 R&D firms, however, the Middle Atlantic states are significant net importers.[29] The primary net exporting regions of the country are the East North Central and South Atlantic. The East North Central region, in particular, trains 56 percent more new industrial S&E Ph.D.s than it hires. Contributing to this region's large net outflow is the fact that Illinois, Indiana and Wisconsin retain less than 30 percent of the Ph.D.s they graduate.

Net flows of highly educated S&E workers conceal much larger gross flows. New York, for example, is a net exporter of 97 new Ph.D.s, which is 11 percent of the total trained in the state. However, the gross outflow from New York is 591, or 66 percent of the total trained. These outflows are largely offset by an inflow of 494 new Ph.D.s from other states.

Sumell et al. note an interesting dynamic in states such as Massachusetts.[30] This state hires 83 percent as many new industrial S&E Ph.D.s as it trains. But only 44 percent of those hired come from in-state universities. Massachusetts has a stay rate of only 36 percent, yet manages to attract a significant number of new Ph.D.s from other states. By training a large number of highly skilled workers, Massachusetts attracts high-tech firms wanting access to a skilled workforce which, in turn, attracts high-skilled workers from other states.

Focusing on the stay rates shown in Exhibit 3.1, the highest rates are in California (68 percent), Texas (54 percent) and New Jersey (46 percent). Each of these states has a strong local demand for scientists and engineers. States with the lowest rates are Indiana (12 percent), Wisconsin (19 percent) and Pennsylvania (24 percent). A state's ability to retain its graduates depends largely on whether its research universities are located in a large consolidated metropolitan area. More than 67 percent of new industrial Ph.D.s that remain in state work in the same CMSA in which they were trained.[31]

Exhibit 3.2 shows stay rates by field of training. Astronomy, with a very small number of new Ph.D.s going to industry, has the highest stay rate. Agriculture, which is dominated by foreign-born students who often return home, has the lowest rate. Outside of these fields, stay rates range from a low of 28 percent in chemistry to a high of 46 percent in medicine. Stay rates for engineering and chemistry are 36 percent, which is the average for the entire sample of new industrial S&E Ph.D.s.

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[29] See P. Stephan, A. Sumell, G. Black and J. Adams, "Doctoral Education and Economic Development: The Flow of New Ph.D.s to Industry," Economic Development Quarterly, May 2004, pp.151-67.

[30] See Sumell, P. Stephan and J. Adams, "The Location Decision of New Ph.D.s Working in Industry," in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment,* The University of Chicago Press, 2009, p. 268.

[31] See Sumell, P. Stephan and J. Adams, "The Location Decision of New Ph.D.s Working in Industry," in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment,* The University of Chicago Press, 2009, p. 268.

## Exhibit 3.2: Percent of New Industrial S&E Ph.D.s Staying in State, by Field of Training

| Field | Total number | Percent staying in state |
|---|---|---|
| Agriculture | 308 | 26.0% |
| Astronomy | 44 | 56.8 |
| Biology | 609 | 45.0 |
| Chemistry | 1,216 | 28.6 |
| Computer science | 762 | 36.4 |
| Earth science | 252 | 28.6 |
| Engineering | 5,364 | 36.3 |
| Math | 477 | 35.0 |
| Medicine | 435 | 46.0 |
| Physics | 654 | 45.0 |
| **All fields** | **10,121** | **36.4** |

***Source:*** *A. Sumell, P. Stephan and J. Adams*[32]

The overall stay rate of 36 percent for industrial S&E Ph.D.s is well below the stay rate of 62 percent for S&E undergraduates. Why are stay rates so much lower for S&E Ph.D.s? Part of the answer has to do with the fact that S&E doctorate recipients have extremely large amounts of highly specialized human capital. For these graduates, the benefits to engaging in geographically extensive job search are likely to outweigh both the costs of that search and the costs of moving long distances.

Other reasons for the high propensity of Ph.D. graduates to leave their state have to do with the supply of graduate education. First, there are substantial fixed costs and economies of scale involved in training Ph.D.s. To provide students with breadth of knowledge and quality training in general research methods, graduate programs must have a large and diverse faculty. In many fields, graduate training also requires expensive equipment. Given that relatively few students go on to pursue a Ph.D., programs must be concentrated in a relatively few geographic areas.

Another factor contributing to the migration of graduates is the fact that many of the top research universities in the U.S. were founded in the east and remain there despite the western movement of people and jobs.

Finally, the nature of funding sources for research universities affects the location decisions of graduates. As noted by Rosenberg and Nelson, in the late 19th century and early part of the 20th century, state governments were the principal source of funding for U.S. research universities.[33] Along with this funding came the expectation that universities would train students for employment in local industries such as agriculture, mining and oil extraction. Between 1940 and 1950, the contribution of the federal government to university revenues exploded, and the nature of

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[32] A. Sumell, P. Stephan and J. Adams, "The Location Decision of New Ph.D.s Working in Industry," in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment*, The University of Chicago Press, 2009, Table 8.4.

[33] See N. Rosenberg and R. Nelson, "American Universities and Technical Advance in Industry," *Research Policy*, 1994, pp.323-48.

university research was transformed. The direction of university research, and the training of its doctoral students, shifted away from practical application in local industry to more basic scientific research, with applications to national goals in defense and health care.

### 3.2.2 Determinants of Migration

States that sustain a high level of employment of highly skilled scientists and engineers do so in large part by being able to attract large numbers of workers from out of state. So what makes a state or city attractive to S&E workers? What determines the location choices of scientists and engineers?

Among personal factors affecting the decision to migrate, one of the most significant is history of prior migration. Foreign-born students are likely to move again once they graduate. On the other hand, students with a history of local residence are likely to remain after graduation. Sumell et al. confirm these tendencies in their study of the migration patterns of new industrial S&E Ph.D.s.[34] Doctorate recipients with temporary resident immigration status, and Asians in particular, display an increased probability of taking a job in another city or state. But doctorates who earn their Ph.D. in the same city or state as their undergraduate degree are more likely to stay. They are especially likely to stay if they also attended high school in the area. These regularities provide one direction for public policy aimed at increasing stay rates among university graduates: make a special effort to recruit local students.

Among place factors, the critical determinant of migration is local demand for workers. This is especially true in the case of highly educated scientists and engineers graduating from top programs.[35] In their study of industrial S&E Ph.D.s, Sumell et al found stay rates to be significantly higher in areas that had a high level of industrial R&D and a high degree of employment absorptive capacity.[36] Champagne-Urbana graduates a large number of new Ph.D.s who want to work in industry. But there are few industry jobs in the city, so the local-area stay rate of the University of Illinois is extremely low. A large local labor market is especially important in light of the frequency with which S&E workers change jobs. As Richard Florida reports from his focus group sessions with technology workers, "young graduates know they will probably change employers as many as three times in ten years, and they will not move to an area where they do not feel there are enough quality employers to provide these opportunities."[37]

How important are amenities and lifestyle factors in the migration decisions of S&E workers? Florida has made a reputation studying the location choices of technology workers, calling special attention to the role of amenities and quality of life in determining the perceived attractiveness of a city. What came across clearly in his interviews was that highly educated technology workers "want to work in progressive environments, frequent upscale shops and cafes, enjoy museums and fine

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[34] See Sumell, P. Stephan and J. Adams, "The Location Decision of New Ph.D.s Working in Industry," in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment,* The University of Chicago Press, 2009.
[35] See R. Freeman and D. Goroff, "Introduction" in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment,* The University of Chicago Press, 2009.
[36] See Sumell, P. Stephan and J. Adams, "The Location Decision of New Ph.D.s Working in Industry," in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment,* The University of Chicago Press, 2009.
[37] See R. Florida, "The Role of the University: Leveraging Talent, not Technology," *Issues in Science and Technology*, 1999, p. 71.

arts and outdoor activities, and send their children to superior schools."[38] Empirical studies of new graduates, however, generally find that amenities are less important than economic factors in explaining location choices. In their own analysis of newly graduating scientists and engineers, Gottlieb and Joseph find that the impact of metropolitan-level amenities is relatively weak.[39] Recreational amenities are never statistically significant. The authors do find city size to be an important attractor, however, and admit that this variable may proxy for both the depth of the local professional job market and the presence of big-city amenities such as restaurants, museums and symphonies.

## 3.3 Where Do Graduates of Arizona's Universities End Up?

To measure the stay rates of Arizona's graduates, alumni data were obtained from each of the state's three major universities. Individual records were assembled for students who graduated between 2000 and 2010. The records provide year of graduation, degree received, field of study and zip code of current home residence. The alumni offices of each university make a considerable effort to maintain complete and accurate files. The records for Arizona State University, for example, cover more than 90 percent of those who have graduated in the past ten years.

When comparing stay rates at Arizona's universities with those reported in Section 3.2 for universities throughout the country, note that Arizona rates are based on the current residence of anyone who has graduated since 2000, while the national rates are based on residence shortly after graduation. Since the likelihood of out-of-state residence increases with time since graduation, stay rates for Arizona's universities will be downward biased in relation to the national figures. Also note that the composition of advanced degrees differs between the two sets of data. Statistics on Arizona graduates with advanced degrees include recipients of both master's degrees and Ph.D.s. The national figures in Section 3.2.1, on the other hand, are for doctorate recipients only. Since stay rates for master's-level graduates are higher than those for Ph.D.s, the stay rates for Arizona graduates with advanced degrees will be upward biased in comparison with the national figures.

Stay rates for graduates of the three state universities are shown in Exhibit 3.3, Exhibit 3.5, and Exhibit 3.7. For each indicated degree, the top figure is the percent of alumni who currently reside in Arizona. The lower figure is the total number of alumni with the indicated degree, including both those with an in-state residence and those who reside out of state.

### 3.3.1 Arizona State University (ASU)

Among all students who received an undergraduate degree from Arizona State University between 2000 and 2010, 72 percent currently reside in Arizona (see Exhibit 3.3). The rate is the same whether the degree is in a science and engineering field or another area. Stay rates for ASU undergraduates are significantly higher than the average of 62 percent for S&E undergraduates at all U.S. colleges and universities. For individual S&E fields, the highest ASU undergraduate stay rates are in electrical engineering (77 percent), computer science (74 percent) and biochemistry (72 percent). The lowest stay rates are for those graduating with degrees in physics (63 percent), microbiology (65 percent), industrial engineering (65 percent) and aerospace engineering (66 percent).

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[38] See R. Florida, "The Role of the University: Leveraging Talent, not Technology," *Issues in Science and Technology*, 1999, p. 71.
[39] See P. Gottlieb and G. Joseph, "College-to-Work Migration of Technology Graduates and Holders of Doctorates within the United States," *Journal of Regional Science,* 2006, pp.627-59.

## Exhibit 3.3: Percent of ASU Alumni Currently Residing in Arizona

| | Highest degree received | |
|---|---|---|
| | Undergraduate Degree | Graduate Degree |
| **Alumni receiving a non-S&E degree** | **72.3%** | **65.1%** |
| | 79,389 | 22,077 |
| **Alumni receiving a S&E degree** | **72.0%** | **47.2%** |
| | 6,800 | 4,148 |
| **By selected S&E fields** | | |
| Aerospace engineering | 66.4% | 58.1% |
| | 259 | 43 |
| Biochemistry | 72.2% | 75.0% |
| | 335 | 20 |
| Bioengineering | 68.4% | 58.3% |
| | 491 | 163 |
| Chemical engineering | 67.9% | 43.6% |
| | 349 | 78 |
| Chemistry | 67.7% | 38.1% |
| | 195 | 168 |
| Computer science | 74.1% | 38.5% |
| | 790 | 738 |
| Electrical engineering | 76.6% | 42.6% |
| | 981 | 1,464 |
| Industrial engineering | 65.1% | 44.7% |
| | 301 | 474 |
| Mathematics | 68.3% | 57.4% |
| | 331 | 148 |
| Mechanical engineering | 71.7% | 51.5% |
| | 799 | 204 |
| Microbiology | 65.2% | 37.5% |
| | 365 | 32 |
| Molecular & cellular biology | 71.3% | 67.9% |
| | 261 | 53 |
| Physics | 63.0% | 62.2% |
| | 119 | 90 |

***Explanatory notes:*** *For each degree, the top figure is the percent of alumni who currently reside in Arizona. The lower figure is the total number of alumni with the indicated degree, including both those with an in-state residence and those who reside out of state. Data cover all alumni who received their first degree from the university during the period 2000-2010. Those receiving multiple degrees are counted only once, by their highest degree.*
***Source:*** *ASU Foundation*

As is true at the national level, the more advanced the degree, the greater is the chance that an ASU graduate will leave the state. For those graduating with a master's or Ph.D. in a science or engineering field, only 47 percent currently live in Arizona. The stay rate is higher (65 percent) for those graduating with an advanced degree in a non-S&E field. ASU produces the largest number of advanced S&E degrees in electrical engineering and computer science. The stay rates for advanced degrees in these fields are 43 percent and 39 percent, respectively.

Shown in Exhibit 3.4 are the particular states in which ASU S&E graduates with advanced degrees now reside. Also shown for comparison are the state distributions of all U.S. S&E workers (column three) and U.S. workers with doctorate degrees (column four). Not surprisingly, the data reveal a strong Western bias in the location decisions of ASU graduates. For example, California is home to 35 percent of ASU graduates who reside in a U.S. state other than Arizona. This is 2½ times the national percentage of S&E workers accounted for by California. Other states with shares of ASU graduates that are significantly higher than their national averages are Washington, Oregon and Texas. States with large shares of national employment but small shares of ASU graduates include New York, Massachusetts and Maryland. It is unclear whether the Western preference among ASU graduates is due to climate or lifestyle preferences or whether it is due to relationships the university and its faculty have with firms located in this part of country.

### Exhibit 3.4: State Residence of ASU Graduate-Degreed Science and Engineering Alumni

| State | Number with a graduate degree from ASU | As a percent of all living outside of AZ | Percent of U.S. S&E workers living outside of AZ | Percent of U.S. S&E Ph.D.s living outside of AZ |
|---|---|---|---|---|
| Arizona | 1,959 | -- | -- | -- |
| Arkansas | 12 | 0.56 | 0.59 | 0.47 |
| California | 755 | 35.10 | 13.30 | 14.32 |
| Colorado | 63 | 2.93 | 2.51 | 2.16 |
| Connecticut | 12 | 0.56 | 1.36 | 1.69 |
| Florida | 42 | 1.95 | 4.56 | 2.89 |
| Georgia | 35 | 1.63 | 2.56 | 2.13 |
| Idaho | 17 | 0.79 | 0.53 | 0.47 |
| Illinois | 74 | 3.44 | 3.96 | 3.95 |
| Indiana | 17 | 0.79 | 1.61 | 1.62 |
| Iowa | 12 | 0.56 | 0.86 | 0.80 |
| Maryland | 35 | 1.63 | 2.89 | 4.29 |
| Massachusetts | 52 | 2.42 | 3.64 | 5.31 |
| Michigan | 27 | 1.26 | 3.33 | 2.93 |
| Minnesota | 23 | 1.07 | 2.33 | 1.93 |
| New Jersey | 64 | 2.98 | 3.38 | 3.41 |
| New Mexico | 38 | 1.77 | 0.70 | 1.36 |
| New York | 51 | 2.37 | 5.86 | 7.52 |
| North Carolina | 41 | 1.91 | 2.75 | 3.10 |
| Ohio | 30 | 1.39 | 3.57 | 3.37 |
| Oregon | 112 | 5.21 | 1.31 | 1.36 |
| Pennsylvania | 52 | 2.42 | 4.05 | 4.77 |
| Tennessee | 13 | 0.60 | 1.24 | 1.64 |
| Texas | 195 | 9.07 | 8.57 | 5.90 |

| | | | | |
|---|---|---|---|---|
| Utah | 34 | 1.58 | 0.97 | 0.90 |
| Virginia | 54 | 2.51 | 4.34 | 3.25 |
| Washington | 174 | 8.09 | 3.43 | 2.77 |
| Wisconsin | 17 | 0.79 | 1.81 | 1.56 |

***Explanatory notes:*** *Data cover alumni who received their first degree from the university during the period 2000-2010. Table only includes states with at least ten ASU alumni in residence. Percentages in column two are calculated using alumni who currently live in the U.S.*
***Sources:*** *Alumni data are from the ASU Foundation; state distribution of U.S. S&E workers is from the Bureau of Labor Statistics; and the state distribution of U.S. S&E Ph.D.s is from the National Science Foundation.*

### 3.3.2 University of Arizona (U of A)

Exhibit 3.5 shows stay rates by degree and field of study for graduates of the University of Arizona. Stay rates for the U of A are uniformly lower than they are for ASU. Of course, Tucson has a much smaller economy than the Phoenix metro area. Students who choose not to stay in the same city as their university often end up leaving the state altogether rather than moving to another city within the state.

### Exhibit 3.5: Percent of U of A Alumni Currently Residing in Arizona

| | **Highest degree received** | |
|---|---|---|
| | **Undergraduate Degree** | **Graduate Degree** |
| **Alumni receiving a non-S&E degree** | **59.7%** | **42.7%** |
| | 48,374 | 11,725 |
| **Alumni receiving a S&E degree** | **65.6%** | **24.4%** |
| | 7,139 | 1,998 |
| **By selected S&E fields** | | |
| Aerospace engineering | 55.1% | 45.5% |
| | 226 | 49 |
| Biochemistry | 66.2% | 19.2% |
| | 473 | 29 |
| Chemical engineering | 62.1% | 30.2% |
| | 286 | 51 |
| Chemistry | 61.5% | 26.9% |
| | 291 | 266 |
| Computer science | 68.8% | 15.9% |
| | 753 | 243 |
| Electrical engineering | 73.5% | 29.1% |
| | 652 | 400 |
| Industrial engineering | 69.2% | 27.3% |
| | 125 | 107 |
| Mathematics | 66.7% | 39.7% |
| | 504 | 66 |
| Mechanical engineering | 70.1% | 37.7% |
| | 768 | 184 |
| Microbiology | 75.3% | 27.1% |
| | 483 | 56 |
| Molecular & cellular biology | 69.8% | 19.2% |
| | 1,350 | 57 |

| | | |
|---|---|---|
| Optical science and engineering | 70.8% | 30.5% |
| | 223 | 295 |
| Physics | 44.6% | 42.5% |
| | 262 | 82 |

***Explanatory notes****: For each degree, the top figure is the percent of alumni who currently reside in Arizona. The lower figure is the total number of alumni with the indicated degree, including both those with an in-state residence and those who reside out of state. Data cover all alumni who received their first degree from the university during the period 2000-2010. Those receiving multiple degrees are counted only once, by their highest degree. Alumni with graduate degrees in medicine and pharmacy are classified in non-S&E fields.*
***Source:*** *University of Arizona Foundation/Alumni Association*

Across all U of A graduates with a bachelor's degree in a science or engineering field, 66 percent currently live in Arizona. Stay rates are highest for undergraduates with degrees in microbiology (75 percent) and electrical engineering (74 percent). The relatively strong science base in the Tucson area may contribute to the fact that stay rates for microbiology majors are higher at the U of A than at ASU. Stay rates for U of A graduates are lowest in the fields of physics (45 percent) and aerospace engineering (55 percent). These fields also showed up as having relatively low stay rates among ASU graduates.

The stay rate is only 24 percent for those graduating from the U of A with an advanced S&E degree. This is one-half the size of the stay rate for the comparable group at ASU. The four fields with the largest number of advanced degrees and their associated stay rates are: electrical engineering (29 percent), optics (31 percent), chemistry (27 percent) and computer science (16 percent).

Exhibit 3.6 provides a breakdown by state of the home residences of U of A graduates with advanced degrees in science and engineering. As is the case with ASU graduates, U of A graduates who choose not to live in Arizona locate disproportionately in other Western states. California, which accounts for 14 percent of all U.S. highly educated S&E workers outside of Arizona, absorbs 24 percent of U of A advanced-degreed S&E graduates who choose to live in a state other than Arizona. Other states in which U of A graduates locate disproportionately are Washington, New Mexico, Idaho and Oregon.

## Exhibit 3.6: State Residence of U of A Graduate-Degreed Science and Engineering Alumni

| State | Number with a graduate degree from U of A | As a percent of all living outside of AZ | Percent of U.S. S&E workers living outside of AZ | Percent of U.S. S&E Ph.D.s living outside of AZ |
|---|---|---|---|---|
| Arizona | 488 | -- | -- | -- |
| California | 287 | 24.28 | 13.30 | 14.32 |
| Colorado | 28 | 2.37 | 2.51 | 2.16 |
| Connecticut | 14 | 1.18 | 1.36 | 1.69 |
| Florida | 26 | 2.20 | 4.56 | 2.89 |
| Georgia | 20 | 1.69 | 2.56 | 2.13 |
| Idaho | 21 | 1.78 | 0.53 | 0.47 |
| Illinois | 56 | 4.74 | 3.96 | 3.95 |
| Indiana | 25 | 2.12 | 1.61 | 1.62 |
| Iowa | 19 | 1.61 | 0.86 | 0.80 |

| | | | | |
|---|---|---|---|---|
| Kansas | 12 | 1.02 | 1.01 | 0.70 |
| Kentucky | 21 | 1.78 | 0.90 | 0.81 |
| Maryland | 26 | 2.20 | 2.89 | 4.29 |
| Massachusetts | 42 | 3.55 | 3.64 | 5.31 |
| Michigan | 17 | 1.44 | 3.33 | 2.93 |
| Minnesota | 27 | 2.28 | 2.33 | 1.93 |
| Missouri | 16 | 1.35 | 1.83 | 1.52 |
| New Jersey | 27 | 2.28 | 3.38 | 3.41 |
| New Mexico | 37 | 3.13 | 0.70 | 1.36 |
| New York | 63 | 5.33 | 5.86 | 7.52 |
| North Carolina | 19 | 1.61 | 2.75 | 3.10 |
| Ohio | 24 | 2.03 | 3.57 | 3.37 |
| Oregon | 28 | 2.37 | 1.31 | 1.36 |
| Pennsylvania | 43 | 3.64 | 4.05 | 4.77 |
| Texas | 78 | 6.60 | 8.57 | 5.90 |
| Utah | 14 | 1.18 | 0.97 | 0.90 |
| Virginia | 29 | 2.45 | 4.34 | 3.25 |
| Washington | 68 | 5.75 | 3.43 | 2.77 |
| Wisconsin | 17 | 1.44 | 1.81 | 1.56 |

***Explanatory notes:*** *Data cover alumni who received their first degree from the university during the period 2000-2010. Table only includes states with at least ten U of A alumni in residence. Percentages in column two are calculated using alumni who currently live in the U.S.*

***Sources:*** *Alumni data are from the University of Arizona Foundation; state distribution of U.S. S&E workers is from the Bureau of Labor Statistics; and the state distribution of U.S. S&E Ph.D.s is from the National Science Foundation.*

### 3.3.3 Northern Arizona University (NAU)

Exhibit 3.7 shows the stay rates of graduates from Northern Arizona University. NAU provides very few advanced degrees in science and engineering. Focusing on the undergraduates, 64 percent of those who received a bachelor's degree in a S&E field still reside in Arizona. This is a much lower stay rate than the comparable figure for ASU, but it is only slightly lower than the U of A stay rate. For the most popular S&E majors at NAU, the stay rates are: 68 percent in computer information systems, 61 percent in mechanical engineering and 60 percent in environmental science.

## Exhibit 3.7: Percent of NAU Alumni Currently Residing in Arizona

| | **Highest degree received** | |
|---|---|---|
| | **Undergraduate Degree** | **Graduate Degree** |
| **Alumni receiving a non-S&E degree** | **69.3%** | **80.4%** |
| | 26,789 | 19,659 |
| **Alumni receiving a S&E degree** | **64.3%** | **58.5%** |
| | 1,699 | 191 |
| **By selected S&E fields** | | |
| Chemistry | 56.2% | 46.7% |
| | 125 | 63 |
| Computer information systems | 68.4% | -- |
| | 482 | 0 |
| Computer science | 76.1% | -- |
| | 71 | 0 |

| | | |
|---|---|---|
| Computer science and engineering | 57.4% | -- |
| | 68 | 0 |
| Electrical engineering | 68.6% | -- |
| | 179 | 0 |
| Environmental sciences | 59.6% | 63.83% |
| | 253 | 52 |
| Mathematics | 75.6% | 64.47% |
| | 96 | 76 |
| Mechanical engineering | 60.8% | -- |
| | 271 | 0 |
| Microbiology | 66.3% | -- |
| | 85 | 0 |
| Physics | 47.8% | -- |
| | 69 | 0 |

***Explanatory notes:*** *For each degree, the top figure is the percent of alumni who currently reside in Arizona. The lower figure is the total number of alumni with the indicated degree, including both those with an in-state residence and those who reside out of state. Data cover all alumni who received their first degree from the university during the period 2000-2010. Those receiving multiple degrees are counted only once, by their highest degree.*
***Source:*** *Northern Arizona University, Office of Alumni Relations*

## 3.4 Does Local Training of S&E Workers Create a Larger Local Workforce?

States that educate and train scientists and engineers are certain to lose a large percentage of them to employers located in other states. But it would be premature to dismiss the role local universities play in determining the size of the local college-educated workforce. There is an undeniable "stickiness" to where people live. A much higher percentage of students, even those with advanced degrees, take jobs and remain in the vicinity of their university than would be expected in a "flat" world where space was unimportant.

Evidence of persistence in the location decisions of students is easy to find. Exhibit 3.8 compares the stay rates of industrial S&E Ph.D.s reported by Sumell et al. with state shares of national employment of doctorate-level S&E workers.[40] The second statistic provides a benchmark measure of what stay rates would be in a market where geography did not matter. Stay rates in California, New York and Pennsylvania are 4-5 times higher than they would be in a "flat" world. In Massachusetts, they are 8 times higher; in Texas, 10 times higher; and in Arizona, 32 times higher!

[40] See Sumell, P. Stephan and J. Adams, "The Location Decision of New Ph.D.s Working in Industry," in R. Freeman and D. Goroff (eds.) *Science and Engineering Careers in the United States: An Analysis of Markets and Employment,* The University of Chicago Press, 2009.

## Exhibit 3.8: Comparing Stay Rates of Newly Trained Ph.D.s with Shares of U.S. Employed S&E Ph.D.s

| State | Percent of new Ph.D.s produced that stay in the state (1997-1999) | Percent of all U.S. employed S&E Ph.D.s (1997) |
|---|---|---|
| Arizona | 40.1% | 1.2% |
| California | 67.8 | 13.6 |
| Colorado | 37.2 | 2.1 |
| Florida | 34.3 | 2.6 |
| Georgia | 28.1 | 1.9 |
| Illinois | 29.3 | 4.1 |
| Indiana | 12.2 | 1.5 |
| Maryland | 23.7 | 4.1 |
| Massachusetts | 36.3 | 4.5 |
| Michigan | 33.0 | 2.9 |
| Minnesota | 36.7 | 1.9 |
| New Jersey | 45.7 | 4.0 |
| New York | 34.2 | 7.8 |
| North Carolina | 28.0 | 2.7 |
| Ohio | 33.0 | 3.6 |
| Pennsylvania | 23.9 | 4.6 |
| Texas | 53.7 | 5.5 |
| Virginia | 30.1 | 3.0 |
| Wisconsin | 18.8 | 1.6 |

***Sources:*** *Stay rates are those reported by Sumell, et al.*[41] *Source of primary data for both columns is the NSF Survey of Earned Doctorates.*

Data for metro areas show retention rates that are much higher than one would expect in a frictionless national market. Among all industrial S&E Ph.D.s trained from 1997-1999, the University of Minnesota trained 86 of the 216 new hires in the Minneapolis-St. Paul metro area; the University of Texas at Austin trained 67 of the 170 hires in Austin; the Georgia Institute of Technology trained 61 of the 116 new Ph.D. hires in Atlanta.[42]

The relationship between state production of college degrees and number of college graduates in a state's population is apparent in correlations between the two variables. Exhibit 3.9 provides a scatter plot of the data from Exhibit 3.1 on number of new S&E Ph.D.s trained in a state against the number of newly trained Ph.D.s hired in that state. Number of Ph.D.s hired is adjusted for weather, as explained by Hill et al.[43] There are clearly some states such as New Jersey that hire many more

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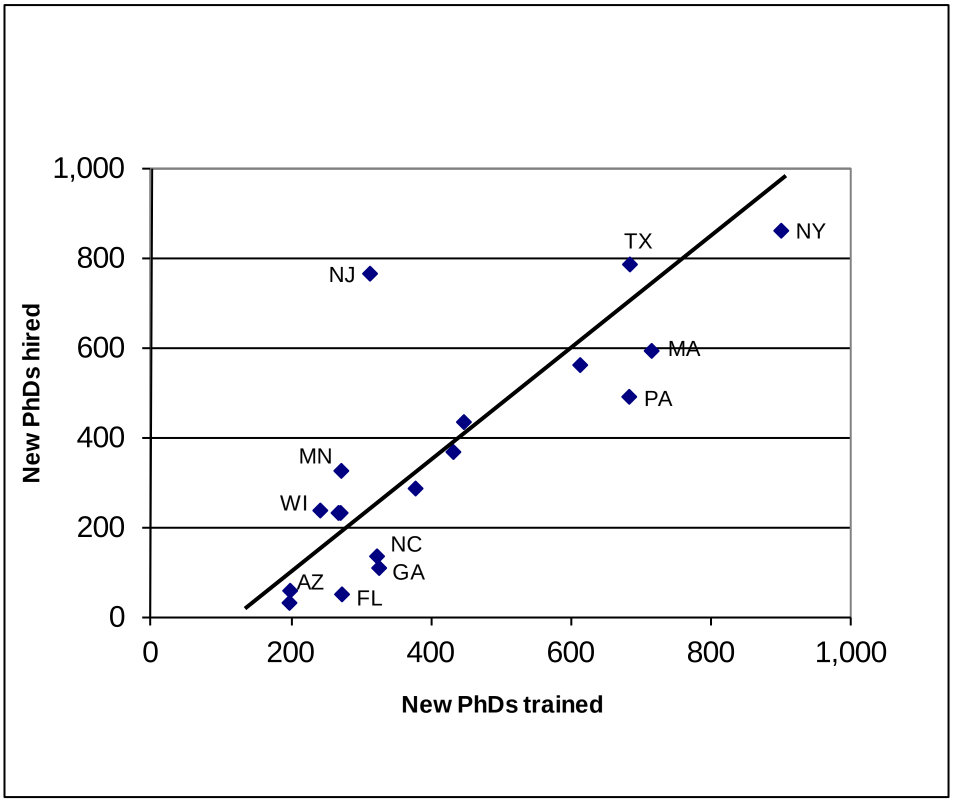
[41] A. Sumell, P. Stephan and J. Adams, "The Location Decision of New Ph.D.s Working in Industry," in R. Freeman and D. Goroff (eds.) Science and Engineering Careers in the United States: An Analysis of Markets and Employment, The University of Chicago Press, 2009, Table 8.2.
[42] See P. Stephan, A. Sumell, G. Black and J. Adams, "Doctoral Education and Economic Development: The Flow of New Ph.D.s to Industry," *Economic Development Quarterly*, May 2004, p. 162.
[43] Weather, the single most important amenity explaining U.S. migration patterns, is correlated with the geographic distribution of U.S. colleges and universities. States with relatively high production of advanced degrees are disproportionately represented in the East and upper Midwest – parts of the

Ph.D.s than can be explained by local production, and there are states such as Pennsylvania that hire fewer Ph.D.s than would be expected from their local production. In general, however, there is a positive and statistically significant relationship between Ph.D.s trained and Ph.D.s produced in a state.

### Exhibit 3.9: Ph.D.s Trained as a Determinant of Ph.D.s Working in a State




***Note:*** *California was included in the regression but excluded from the diagram because its size distorts the scale.*

Why do many college graduates stick around and find jobs in the same city or state as their school? In some cases, there are personal reasons. Students with family who were born in or attended high school in an area may have a strong preference for staying, provided they can get a good education. The strength of the local job market is a critical conditional factor, of course. But there is much evidence that the presence of a university, especially a top-rated research university, serves to attract high-tech employers.[44] As argued by Malecki and Bradbury, industrial R&D operations are seriously constrained by the labor market for scientists and engineers, and availability of scientific

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country with undesirable weather. Because of the relationship between weather and degrees awarded, a simple correlation between degrees awarded and PhDs hired will understate the causal role played by local production. See K. Hill, D. Hoffman and T. Rex, "The Value of Higher Education: Individual and Societal Benefits," *Center for Competitiveness and Prosperity Research,* Arizona State University, October 2005.

[44] For a full discussion of the role research universities play in local economic development, see K. Hill, "University Research and Local Economic Development," in News and Views, A Publication of the Economic Development Division of the American Planning Association, Summer 2008, pp.14-16.

labor is an important locational consideration.[45] Firms are particular, however, about the institutions they rely on for new researchers and, especially among large firms, only the best programs are an attracting factor.

It is not only the students but the faculty at top research universities that stimulate local high-tech activity and indirectly provide local employment opportunities. As argued by Zucker, Darby, and others, "metamorphic" innovations – those associated with the creation of new industries or the radical transformation of an existing industry – typically are driven by breakthrough discoveries in science and engineering.[46] Examples include integrated circuits, recombinant DNA and nanotechnology. These kinds of discoveries are not well understood initially and cannot be codified. A transfer and application to industry requires bench-level relationships between industry scientists and the pioneering scientist. If the scientist making the metamorphic discovery has a university appointment that he wishes to maintain and does not want to commute long distances, he will serve as a fixed factor that determines the location of new firms entering the market to develop the new technology.

Does local training of scientists and engineers create a larger local S&E workforce? It is an imperfect relationship, and policymakers would be well advised not to exaggerate it. But there is clearly inertia in people's location decisions. As noted by Gottlieb and Joseph in their extensive analysis of the location decisions of S&E graduates, "all of the models estimated show a large and significant tendency among college graduates to stay rather than migrate, other things equal. This suggest that, in the long run, training a relatively large number of university graduates in a metropolitan area could lead to a larger number of knowledge workers settling there."[47] Stay rates are much lower for Ph.D.s than for those getting bachelor's degrees. Economies of scale make it inevitable that firms may have to look out of state for doctorate-level workers with highly specialized training. Even in the case of workers with advanced degrees, however, the graduates and the faculty that train them can serve as a magnet for high-tech firms, especially if the faculty are pioneering researchers and the students are an important part of the transmission of that knowledge to industry.

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[45] See E. Malecki, "The R&D Location Decision of the Firm and 'Creative' Regions – A Survey," *Technovation,* 1987, pp.205-22. Also see E. Malecki and S. Bradbury, "R&D Facilities and Professional Labour: Labour Force Dynamics in High-Technology," *Regional Studies*, 1992, pp.123-35.

[46] See L. Zucker, M. Darby and M. Brewer, "Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises," *American Economic Review,* 1998, pp.290-306. See also M. Darby and L. Zucker, "Growing by Leaps and Inches: Creative Destruction, Real Cost Reduction and Inching Up," *Economic Inquiry*, 2003, pp.1-19.

[47] P. Gottlieb and G. Joseph, "College-to-Work Migration of Technology Graduates and Holders of Doctorates within the United States," *Journal of Regional Science*, 2006, p.653.

# 4 Employment and Earnings of S&E Workers in Arizona

## 4.1 Overview

This chapter presents descriptive statistics on the Arizona market for scientists and engineers. Data on employment provide a measure of how S&E-intensive the Arizona economy is relative to other states in the nation. Data on wages of S&E workers indicate whether shortages of science and engineering workers have been more acute in Arizona than in the rest of the country.

Section 4.2 provides information on the importance of S&E workers to Arizona and other states in the nation. Arizona is a relatively science and engineering intensive state. Science and engineering workers account for 5.42 percent of total Arizona employment. This is slightly higher than the 5.24 percent share of S&E workers in U.S. employment.

Engineering occupations are particularly well represented in Arizona. The state accounts for 2.18 percent of U.S. workers in architecture and engineering occupations, as compared with a 1.86 percent share of all U.S. workers. The representation of engineers in the state's economy is particularly high in aerospace, electrical and electronics, materials and computer hardware. Based on shares of state employment accounted for by architects and engineers, Arizona ranks 13th highest among the 50 states and the District of Colombia. Among Western states, Arizona is less engineering intensive than Washington, New Mexico, Colorado and California, but more engineering intensive than Utah, Oregon and Nevada.

Arizona ranks 17th highest in the nation in shares of state employment accounted for by workers in computer and mathematical occupations. Among Western states, Arizona is less intensive in computer-related occupations than Washington, Colorado, California and Utah. However, computer-related occupations are more highly represented in Arizona than in Oregon, New Mexico and Nevada.

Arizona ranks 27th among the states in shares of science employment. Workers in life, physical and social science occupations account for .76 percent of total Arizona employment, as compared with a share of .84 percent of national employment.

One reason for singling out science and engineering from all other occupations in the economy is that S&E workers are integral to the process of innovation and the production of commercially useful knowledge. Section 4.3 presents information on the importance of knowledge-producing businesses to the Arizona economy. Establishments involved in the production of commercially useful knowledge are referred to with the term "high-tech."

High-tech industries that are highly represented in Arizona include aerospace and parts (where Arizona has a 5.76 percent share of national employment), semiconductors and other electronic components (3.81 percent), navigational and control instruments (3.02 percent), data processing (2.87 percent), and optical instrument manufacturing (2.10 percent). In each of these industries, Arizona's share of U.S. employment exceeds the state's 1.93 percent share of U.S. total private-sector employment.

In 2008, 6.5 percent of Arizona workers were employed in high-tech industries, slightly higher than the national average of 6.2 percent. Among Western states, Arizona ranked 5th highest on the basis of shares of private employment in high-tech industries. Western states with the largest shares were Washington (10.2 percent), Colorado (9.0 percent), California (8.7 percent) and Utah (7.5 percent).

From 1998-2008, Arizona high-tech employment fell sharply as a percent of total state employment. This occurred not because high-tech employment in the state lagged the nation, but because of unusually rapid growth in other areas of the Arizona economy.

Section 4.4 provides information on the wages and salaries earned by science and engineering workers in Arizona. Wage levels are an indicator of labor scarcity. By comparing Arizona wages with U.S. wages, it is possible to gain some insight into the question of whether Arizona firms have been unusually constrained by an availability of S&E workers.

Arizona S&E workers generally earn less than their U.S. counterparts. In 2010, wages of Arizona workers in architecture and engineering were 98 percent of the wages of U.S. workers in this group. Mean annual wages for Arizona workers in computer and mathematical occupations were 96 percent of U.S. levels. For workers in life, physical and social science occupations, Arizona wages were only 85 percent as high as U.S. wages.

Before drawing conclusions about relative labor scarcity from wage data for broad occupational groups, it is necessary to (1) adjust for differences in the detailed mix of occupations between Arizona and the U.S. and (2) acknowledge that wages may differ between states as an offset to differences in climate, amenities, or cost of living. Wages have always been lower in Arizona than in the nation, but this is partly attributed to a preference workers have for living in regions with a warm and dry climate. Labor shortages at the state level for a given occupation group may manifest themselves not through wages that are higher in the state than in the nation, but in a state/national wage differential that is higher than the average differential across all occupations.

To provide a comparison of Arizona and U.S. wages that is more meaningful as an indicator of relative labor shortages in a state, mean U.S. wages are calculated using the Arizona mix of detailed occupations to average U.S. wages across individual occupations. Wages in Arizona are then compared with mean adjusted U.S. wages across all 22 major occupational groups, not just the three relating to science and engineering. Data are presented for two years: 2000 and 2010. In 2000, the average ratio of Arizona wages to U.S. wages was 94 percent when looking across all occupations. The ratio for computer and mathematical occupations was 3rd highest among the 22 groups. The wage ratio for workers in architecture and engineering occupations was 4th highest. Neither of these ratios was above 100 percent, but each was significantly above average. In 2010, the ratios of Arizona wages to U.S. wages were again above average in computer-related and engineering occupations, but by a smaller margin. The ratio for architecture and engineering occupations was 6th highest among the 22 groups, and the ratio for computer and mathematical occupations was 9th highest. In both 2000 and 2010, the ratio of Arizona to U.S. wages for workers in life, physical and social science occupations was well below the average across all occupations.

If wages are used as an indicator of labor scarcity, there is some evidence that Arizona may have faced greater shortages of scientists and engineers than was typical across the nation. This seems to have been truer in 2000 than in 2010. Any Arizona-specific shortages of S&E workers were limited to computer scientists and engineers. There is no indication that the state has faced shortages of workers in life, physical and social science occupations, outside of health care practitioners.

## 4.2 S&E Employment in Arizona

Exhibit 4.1 provides a detailed breakdown of science and engineering employment in Arizona in 2010. Arizona is a relatively science and engineering intensive state. A total of 128,280 S&E workers are employed in Arizona. This represents 1.93 percent of U.S. S&E employment, which is slightly higher than Arizona's 1.86 percent share of overall employment in the nation. Engineering occupations are particularly well represented in Arizona. The state accounts for 2.18 percent of U.S. workers in architecture and engineering occupations. The representation of engineers in the state's economy is especially high in aerospace, electrical and electronics, materials and computer hardware. Arizona accounts for 1.83 percent of U.S. workers in computer science and mathematical occupations, which is slightly lower than the state's share of overall national employment. Firms in Arizona employ a relatively large number of database administrators and systems software developers, but relatively few who work in applications software development. S&E occupations that are least important to the Arizona economy are those in the life and physical sciences. Arizona accounts for less than 1 percent of U.S. biochemists and microbiologists and only 1.3 percent of the nation's chemists.

### Exhibit 4.1: Arizona Employment in Selected Detailed S&E Occupations, 2010

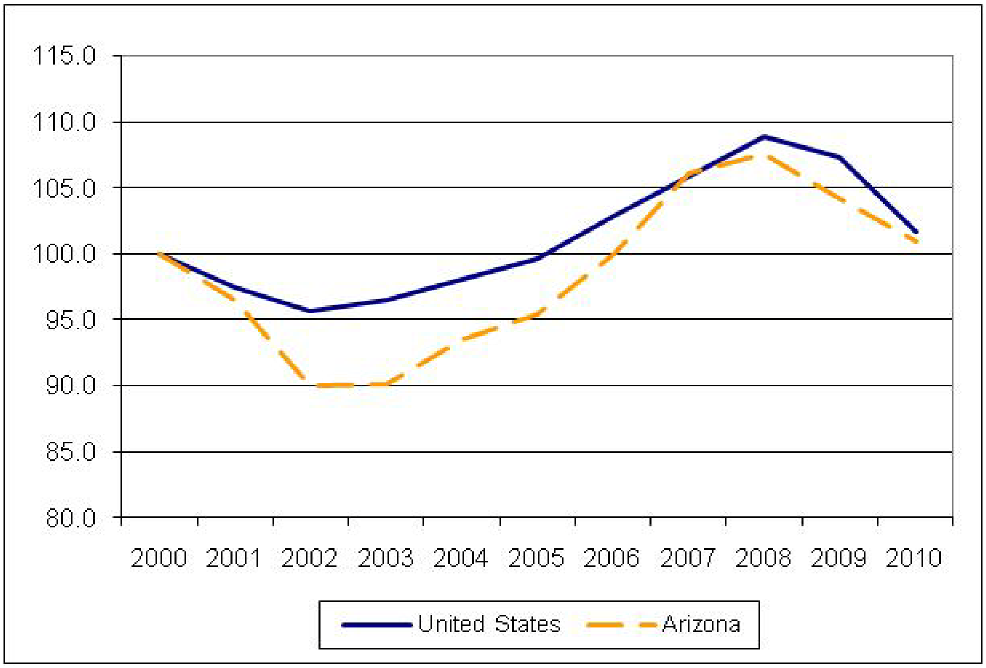
| Occ code | Occ title | Number in AZ | As percent of U.S. employment |
|---|---|---|---|
| 15-0000 | **Computer and Mathematical Occupations** | **60,090** | **1.83%** |
| 15-1121 | Computer Systems Analysts | 8,890 | 1.79 |
| 15-1131 | Computer Programmers | 6,710 | 2.01 |
| 15-1132 | Software Developers, Applications | 6,580 | 1.32 |
| 15-1133 | Software Developers, Systems Software | 8,660 | 2.29 |
| 15-1141 | Database Administrators | 2,760 | 2.65 |
| 15-1142 | Network and Computer Systems Administrators | 6,570 | 1.97 |
| 15-1150 | Computer Support Specialists | 12,280 | 2.12 |
| 15-1179 | Information Security Analysts, Web Developers, | 4,020 | 1.65 |
| | and Computer Network Architects | | |
| 17-0000 | **Architecture and Engineering Occupations** | **50,210** | **2.18** |
| 17-2011 | Aerospace Engineers | 2,390 | 3.05 |
| 17-2031 | Biomedical Engineers | 290 | 1.90 |
| 17-2041 | Chemical Engineers | 250 | 0.87 |
| 17-2061 | Computer Hardware Engineers | 2,040 | 3.05 |
| 17-2071 | Electrical Engineers | 4,530 | 3.04 |
| 17-2072 | Electronics Engineers | 4,800 | 3.59 |
| 17-2112 | Industrial Engineers | 4,330 | 2.13 |
| 17-2131 | Materials Engineers | 770 | 3.53 |
| 17-2141 | Mechanical Engineers | 2,950 | 1.26 |
| 17-3012 | Electrical and Electronics Drafters | 740 | 2.65 |
| 17-3013 | Mechanical Drafters | 1,430 | 2.22 |
| 17-3021 | Aerospace Engineering and Operations Technicians | 400 | 4.72 |
| 17-3023 | Electrical and Electronics Engineering | 4,620 | 3.13 |

| | | | |
|---|---|---|---|
| | Technicians | | |
| 17-3024 | Electro-Mechanical Technicians | 230 | 1.44 |
| 17-3026 | Industrial Engineering Technicians | 2,690 | 4.36 |
| 17-3027 | Mechanical Engineering Technicians | 1,150 | 2.60 |
| 19-0000 | **Life, Physical and Social Science Occupations** | **17,980** | **1.69** |
| 19-1021 | Biochemists and Biophysicists | 120 | 0.53 |
| 19-1022 | Microbiologists | 140 | 0.76 |
| 19-2031 | Chemists | 1,010 | 1.26 |
| 19-2032 | Materials Scientists | 100 | 1.19 |
| 19-4031 | Chemical Technicians | 900 | 1.51 |
| | **All S&E Occupations** | **128,280** | **1.93** |
| | **All Occupations** | **2,367,120** | **1.86** |

***Source:*** *BLS, Occupational Employment Statistics*

Exhibit 4.2 shows the dynamics of growth in Arizona and U.S. science and engineering employment over the past decade. Many industries that employ large numbers of engineers and other S&E workers are highly cyclical. This is apparent in the figure. National S&E employment fell 4 percent during the recession which hit the nation in the early part of the decade. U.S. employment of S&E workers rebounded from 2002-2008, but then fell 7 percent in the latest recession. Because of a heavy representation of electronics and semiconductor production in the state, Arizona's S&E employment is even more cyclical than the nation. Arizona employment of scientists and engineers fell 10 percent from 2000-2002. S&E employment in the state then increased 20 percent from 2002-2008 to reach a share of national employment similar to what it had been in 2000. From 2008-2010, Arizona S&E employment dropped 6 percent, which was about the same as the percentage decrease registered at the national level.

### Exhibit 4.2: Growth in U.S. and Arizona S&E Employment, 2000-2010 (Index 2000=100)




***Source:*** *BLS, Occupational Employment Statistics*

How important is science and engineering to the Arizona economy? How does Arizona compare with other states? Exhibit 4.3, Exhibit 4.4, Exhibit 4.5, and Exhibit 4.6 provide answers to these questions using employment numbers for 2010. Summing over all S&E occupations, science and engineering workers account for 5.42 percent of total Arizona employment. This is slightly higher than the 5.24 percent share of S&E workers in U.S. employment (see Exhibit 4.3). On this basis, Arizona would be said to be a relatively S&E-intensive state.[48] Among the 50 states and the District of Colombia, Arizona ranks 20th highest in share of employment accounted for by S&E workers. S&E employment is most important in the District of Colombia, with a share of total employment that is 86 percent greater than the share in Arizona. Science and engineering employment is also highly important in Washington, Virginia and Maryland, with shares approximately 50 percent greater than Arizona's. Among Western states, Washington, Colorado, California, New Mexico, Utah and Oregon all have higher S&E shares of state employment than does Arizona.

[48] This same conclusion was reached in a different way in Exhibit 4.1. To say that Arizona's share of national employment of scientists and engineers is greater than its share of overall U.S. employment is to say that S&E employment as a share of total employment is higher in Arizona than it is in the nation.

### Exhibit 4.3: State Employment in All S&E Occupations as a Percent of Total State Employment, 2010

| **Top 25 States** | **Percent** |
|---|---|
| District of Columbia | 10.09% |
| Washington | 8.22 |
| Virginia | 8.15 |
| Maryland | 7.91 |
| Massachusetts | 7.68 |
| Colorado | 7.62 |
| Alaska | 6.53 |
| California | 6.27 |
| Delaware | 6.19 |
| Idaho | 6.09 |
| New Mexico | 6.07 |
| Minnesota | 5.83 |
| Michigan | 5.80 |
| New Jersey | 5.79 |
| New Hampshire | 5.60 |
| Utah | 5.57 |
| Oregon | 5.54 |
| Texas | 5.50 |
| Connecticut | 5.50 |
| **Arizona** | **5.42** |
| Vermont | 5.28 |
| Montana | 4.88 |
| Rhode Island | 4.76 |
| North Carolina | 4.75 |
| Alabama | 4.71 |
| **United States** | **5.24** |

***Source:*** *BLS, Occupational Employment Statistics*

Exhibit 4.4 focuses on the relative importance to states of workers in computer and mathematical occupations. Arizona ranks 17$^{th}$ with a share of 2.54 percent. States with the highest representation of computer scientists in their workforce are the District of Colombia, Virginia, Maryland, Washington, Colorado and Massachusetts. These rankings reveal how information-intensive the operations of the federal government are. Among Western states, Arizona is less intensive in computer-related occupations than Washington, Colorado, California and Utah. However, computer-related occupations are more highly represented in Arizona than in Oregon, New Mexico and Nevada.

## Exhibit 4.4: Employment in Computer and Mathematical Occupations as a Percent of Total State Employment, 2010

| Top 25 States | Percent |
|---|---|
| District of Columbia | 5.19% |
| Virginia | 5.14 |
| Maryland | 4.07 |
| Washington | 4.01 |
| Colorado | 4.01 |
| Massachusetts | 4.01 |
| New Jersey | 3.47 |
| Minnesota | 3.15 |
| Delaware | 3.04 |
| California | 3.00 |
| New Hampshire | 2.98 |
| Utah | 2.79 |
| Missouri | 2.72 |
| Connecticut | 2.65 |
| Texas | 2.61 |
| Georgia | 2.59 |
| **Arizona** | **2.54** |
| North Carolina | 2.47 |
| Nebraska | 2.44 |
| New York | 2.43 |
| Ohio | 2.43 |
| Rhode Island | 2.39 |
| Oregon | 2.35 |
| Illinois | 2.30 |
| Idaho | 2.29 |
| **United States** | **2.58** |

***Source:*** *BLS, Occupational Employment Statistics*

The comparative importance of architecture and engineering employment is detailed in Exhibit 4.5. Arizona ranks 13th highest with a share of state employment accounted for by workers in this category of 2.12 percent. This is 17 percent higher than the share of architects and engineers in national employment. The three states with the highest shares are Michigan (autos), Alaska (oil) and Washington (aircraft). Among Western states, Arizona is less engineering intensive than Washington, New Mexico, Colorado and California, but more engineering intensive than Utah, Oregon and Nevada.

### Exhibit 4.5: Employment in Architecture and Engineering Occupations as a Percent of Total State Employment, 2010

| Top 25 States | Percent |
|---|---|
| Michigan | 2.94% |
| Alaska | 2.89 |
| Washington | 2.85 |
| New Mexico | 2.68 |
| Colorado | 2.44 |
| Maryland | 2.36 |
| Massachusetts | 2.27 |
| Virginia | 2.24 |
| Idaho | 2.20 |
| Alabama | 2.19 |
| Texas | 2.15 |
| California | 2.14 |
| **Arizona** | **2.12** |
| Connecticut | 2.07 |
| Vermont | 2.01 |
| South Carolina | 1.99 |
| District of Columbia | 1.97 |
| New Hampshire | 1.96 |
| Utah | 1.93 |
| Oregon | 1.91 |
| Wyoming | 1.89 |
| Minnesota | 1.83 |
| Delaware | 1.82 |
| Louisiana | 1.79 |
| Kansas | 1.76 |
| **United States** | **1.81** |

***Source:*** *BLS, Occupational Employment Statistics*

Comparative statistics for life, physical and social science occupations are shown in Exhibit 4.6. Arizona does not rank among the top 25 states in science employment. Workers in these occupations account for .76 percent of total Arizona employment, as compared with a share of .84 percent of national employment. Western states with relatively high shares of science employment are New Mexico, Oregon, Colorado, California and Utah.

### Exhibit 4.6: Employment in Life, Physical and Social Science Occupations as a Percent of Total State Employment, 2010

| Top 25 States | Percent |
|---|---|
| District of Columbia | 2.94% |
| Alaska | 2.03 |
| Montana | 1.86 |
| New Mexico | 1.66 |
| Idaho | 1.59 |
| Wyoming | 1.54 |
| Maryland | 1.47 |
| Massachusetts | 1.40 |
| Washington | 1.35 |
| Delaware | 1.34 |
| Oregon | 1.28 |
| Colorado | 1.17 |
| California | 1.13 |
| Hawaii | 1.12 |
| South Dakota | 1.03 |
| Vermont | 0.99 |
| North Carolina | 0.93 |
| New Jersey | 0.91 |
| Minnesota | 0.86 |
| Utah | 0.85 |
| West Virginia | 0.82 |
| North Dakota | 0.79 |
| New York | 0.78 |
| Maine | 0.77 |
| Virginia | 0.77 |
| **Arizona (ranks 27th)** | **0.76** |
| **United States** | **0.84** |

***Source:*** *BLS, Occupational Employment Statistics*

## 4.3 High-Technology Industry in Arizona

One reason for singling out science and engineering from all other occupations is that S&E workers, especially those with advanced degrees, are integral to the process of innovation and the production of commercially useful knowledge. Innovation has been the primary driver of advancement in living standards throughout human history. In the long run, the lion's share of the economic gains from innovation accrues to consumers throughout the world, whether they live inside or outside of the innovating region. There are, however, important short-term benefits (or "rents") which are realized by innovating firms and their workers. States and countries would like to be involved in the production of new products and processes and not simply a consumer of them. Also, because of agglomeration economies and the local spillover of new knowledge, innovative activity tends to be self-reinforcing. Areas which are selected as sites for knowledge creation, whether because of policy incentives or a quirk of history, are better able to build on that strength and remain centers of innovation even in the face of high wages and land prices (think Silicon Valley).

This section presents information on the importance of knowledge-producing businesses to the Arizona economy. Establishments involved in the production of commercially useful knowledge are often referred to with the term "high-technology". There is no universally accepted way of identifying "high-tech" activity using publically available data collected in government surveys. For this project, the definition outlined in the report "High-Technology Activities in Arizona: 2007 Update" which was prepared by the Seidman Research Institute for the Arizona Department of Commerce was followed.[49] The sector referred to as "high-tech" is defined by the industries and their NAICS (North American Industry Classification System) codes shown in Exhibit 4.7. The scale or size of high-tech activity in a state or region is measured using employment in these industries. Employee counts are not limited to scientists or engineers, but include all employees of establishments in the high-tech industry group. Data on employment by industry is obtained from the U.S. Bureau of the Census *County Business Patterns.* At the time the tables of this report were prepared, the most recent year for which data were available was 2008.

## Exhibit 4.7: Definition of High-Technology

| NAICS code | NAICS title |
|---|---|
| | **Manufacturing** |
| 3254 | Pharmaceuticals and Medicine |
| 333314 | Optical Instrument and Lens Manufacturing |
| 3341 | Computer and Peripheral Equipment |
| 3342 | Communications Equipment |
| 3343 | Audio and Video Equipment |
| 3344 | Semiconductors and Other Electronic Components |
| 3345 | Navigational, Measurement and Control Instruments |
| 3364 | Aerospace Products and Parts |
| | **Wholesale Trade** |
| 4234 | Professional and Commercial Equipment and Supplies |
| | **Information** |
| 5112 | Software Publishers |
| 517 | Telecommunications |
| 51913 | Internet Publishing and Broadcast and Web Search Portals |
| 5182 | Data Processing, Hosting and Related |
| | **Professional, Scientific and Technical Services** |
| 54133 | Engineering Services |
| 54138 | Testing Laboratories |
| 5415 | Computer Systems Design and Related |
| 5417 | Scientific Research and Development |

Exhibit 4.8 provides a detailed breakdown of Arizona employment by individual high-tech industry for 1998 and 2008. The exhibit also shows the shares of U.S. employment accounted for by Arizona. Arizona is a relatively high-tech state compared to the nation as a whole. In 2008, for example, Arizona accounted for 2.03 percent of U.S. high-tech employment but only 1.93 percent of U.S. total private employment. High-tech industries that are highly represented in Arizona are aerospace and

[49] Center for Competitiveness and Prosperity Research, L. William Seidman Research Institute, W. P. Carey School of Business, Arizona State University, "High-Technology Activities in Arizona: 2007 Update" September 2007.

parts (where Arizona has a 5.76 percent share of national employment), semiconductors and other electronic components (3.81 percent), navigational and control instruments (3.02 percent), data processing (2.87 percent), and optical instrument manufacturing (2.10 percent).

### Exhibit 4.8: Arizona High-Tech Employment by Detailed Industry, 1998 and 2008

| NAICS code | NAICS title | Number in Arizona | | As a percent of U.S. employment | |
|---|---|---|---|---|---|
| | | 1998 | 2008 | 1998 | 2008 |
| 3254 | Pharmaceuticals and Medicine | 1,284 | 1,255 | 0.59% | 0.50% |
| 333314 | Optical Instrument and Lens Manufacturing | 308 | 357 | 1.42 | 2.10 |
| 3341 | Computer and Peripheral Equipment | 1,738 | 418 | 0.71 | 0.46 |
| 3342 | Communications Equipment | 6,328 | 1,727 | 2.29 | 1.43 |
| 3343 | Audio and Video Equipment | 584 | 140 | 1.78 | 0.99 |
| 3344 | Semiconductors and Other Electronic Components | 27,444 | 13,368 | 4.67 | 3.81 |
| 3345 | Navigational, Measurement and Control Instruments | 11,120 | 12,387 | 2.28 | 3.02 |
| 3364 | Aerospace Products and Parts | 22,893 | 23,916 | 4.41 | 5.76 |
| 4234 | Professional and Commercial Equipment and Supplies | 12,484 | 13,222 | 1.72 | 1.83 |
| 5112 | Software Publishers | 4,890 | 5,629 | 1.73 | 1.46 |
| 517 | Telecommunications | 18,352 | 20,655 | 1.76 | 1.72 |
| 51913 | Internet Publishing and Broadcasting and Web Search Portals | 583 | 658 | 0.69 | 0.74 |
| 5182 | Data Processing, Hosting and Related | 3,477 | 11,230 | 1.30 | 2.87 |
| 54133 | Engineering Services | 12,246 | 16,894 | 1.54 | 1.69 |
| 54138 | Testing Laboratories | 2,090 | 2,115 | 2.32 | 1.89 |
| 5415 | Computer Systems Design and Related | 12,588 | 20,586 | 1.44 | 1.55 |
| 5417 | Scientific Research and Development | 2,484 | 8,090 | 0.80 | 1.28 |
| | **All high-tech industries** | **140,893** | **152,647** | **2.05** | **2.03** |
| | **All private industries** | **1,763,509** | **2,385,184** | **1.63** | **1.93** |

***Source:*** *U.S. Census Bureau, County Business Patterns*

Exhibit 4.8 shows the changes in high-tech employment that occurred in Arizona over the period 1998-2008. Arizona has lost 14,100 or 51 percent of its workforce in establishments that produce semiconductors and other electronic components and 4,600 or 73 percent of those employed in the production of communications equipment. There were also significant job losses at the national level during this period, however, so Arizona did not suffer such a steep decline in its shares of U.S. employment in these industries. Arizona's job losses in some high-tech industries were more than offset by job gains in computer systems design, data processing, scientific research and development and engineering services. Total high-tech employment in Arizona actually increased by 8.3 percent over the period, and its share of U.S. high-tech employment has changed very little.

High-tech employment in Arizona has kept pace with national high-tech employment, but not with employment in the rest of the Arizona economy. In 1998, Arizona's share of U.S. high-tech employment was 26 percent higher than its share of total U.S. private employment. By 2008, its share of U.S. high-tech was only 5 percent higher than its share of total national private employment. While Arizona continues to be a relatively high-tech state in comparison with other states in the nation, the margin by which this is true has diminished over the past decade. High-tech employment as a percent of total employment in the state has come to more closely resemble the national average.

Exhibit 4.9 compares shares of U.S. high-technology employment for Arizona, seven other Western states, and eight other states with a large high-tech sector. California dominates the list with a share of U.S. high-tech employment equal to 15.8 percent in 2008. Other states that top the list include Texas (8.2 percent), New York (5.3 percent), Virginia (4.4 percent) and New Jersey (4.4 percent). Among Western states, Arizona has the 4th largest high-tech sector behind California, Washington and Colorado. The exhibit also shows what the state shares of national high-tech employment were in 1998. By comparing these with the shares in 2008, it is possible to identify shifts in the state distribution of U.S. high-tech employment. There has been a noticeable decline in the shares of national high-tech activity accounted for by California and Massachusetts. States registering an increase in share of national activity include Virginia, Texas and New Jersey. As previously noted, Arizona's share of U.S. high-tech employment has scarcely changed.

### Exhibit 4.9: State High-Tech Employment as a Percent of U.S. High-Tech Employment, 1998 and 2008

| Selected States | Percent in 1998 | Percent in 2008 |
|---|---|---|
| Arizona | 2.1% | 2.0% |
| California | 17.2 | 15.8 |
| Colorado | 2.5 | 2.5 |
| Maryland | 2.6 | 2.9 |
| Massachusetts | 4.4 | 3.9 |
| Minnesota | 2.2 | 2.1 |
| Nevada | 0.3 | 0.6 |
| New Jersey | 4.0 | 4.4 |
| New Mexico | 0.6 | 0.5 |
| New York | 5.3 | 5.2 |
| Oregon | 1.3 | 1.2 |
| Pennsylvania | 3.9 | 3.7 |
| Texas | 7.7 | 8.2 |
| Utah | 1.0 | 1.1 |
| Virginia | 3.9 | 4.4 |
| Washington | 3.4 | 3.4 |

***Source:*** *U.S. Census Bureau, County Business Patterns*

Exhibit 4.10 provides a different comparison of high-tech activity across individual U.S. states. The exhibit shows for 1998 and 2008 the percent of total private-sector employment in a state that takes place in high-technology industries. These statistics reveal which states have economies that are most heavily oriented toward high-tech activity. In 2008, 6.2 percent of national private employment was in high-tech industry. All but two of the states in the exhibit had a greater concentration of high-tech activity than the national average. The relative importance of high-tech industry to the Arizona economy was 6.5 percent, only slightly above the national average. Among Western states, Arizona ranked 5th highest on the basis of this measure. Western states with the largest shares of state private employment in high-tech industries were Washington (10.2 percent), Colorado (9.0 percent), California (8.7 percent) and Utah (7.5 percent). Comparing shares in 1998 with those in 2008, there was a slight decline in the share of U.S. private employment accounted for by high-tech industries. Eleven of the sixteen states in the exhibit registered a decline in high-tech employment as a share of total private employment. The high-tech share of total employment fell most sharply in Arizona. This was not because high-tech employment in Arizona lagged the nation, but because other sectors of the Arizona economy grew so rapidly.

### Exhibit 4.10: State High-Tech Employment as a Percent of Total State Private Employment, 1998 and 2008

| Selected States | Percent in 1998 | Percent in 2008 |
|---|---:|---:|
| Arizona | 8.0% | 6.5% |
| California | 9.8 | 8.7 |
| Colorado | 9.9 | 9.0 |
| Maryland | 9.3 | 9.8 |
| Massachusetts | 10.2 | 9.6 |
| Minnesota | 6.5 | 6.2 |
| Nevada | 3.0 | 3.6 |
| New Jersey | 8.1 | 9.0 |
| New Mexico | 7.7 | 6.5 |
| New York | 5.2 | 5.2 |
| Oregon | 6.6 | 6.3 |
| Pennsylvania | 5.4 | 5.4 |
| Texas | 7.0 | 6.7 |
| Utah | 7.6 | 7.5 |
| Virginia | 9.9 | 10.4 |
| Washington | 10.9 | 10.2 |
| United States | 6.3 | 6.2 |

***Source:*** *U.S. Census Bureau, County Business Patterns*

## 4.4 Wages of S&E Workers in Arizona

This section provides information on the wages and salaries earned by science and engineering workers in Arizona. The data are presented once again by occupational category. By comparing Arizona wages with U.S. wages, it is possible to gain some insight into whether shortages of S&E workers have been more acute in Arizona than in the country as a whole.

Exhibit 4.11 shows mean annual wages of S&E workers in Arizona and the U.S. by detailed occupation for 2010. There can be significant statistical sampling error in wage estimates for detailed occupations at the state level. So the reader should resist reading too much into wage estimates for Arizona for any one detailed category. One can have greater confidence, however, in wage estimates for broad occupational groups. Looking at the three broad groups, Arizona S&E workers generally earn less than their U.S. counterparts. Wages of Arizona workers in architecture and engineering are, on average, 98 percent of U.S. workers in this group. Mean annual wages for Arizona workers in computer and mathematical occupations are 96 percent of U.S. levels. For workers in life, physical and social science occupations, Arizona wages are only 85 percent as high as U.S. wages. There are wide variations in wage differentials across detailed occupational categories. Within architecture and engineering, for example, wages of Arizona industrial engineers are 19 percent higher, and wages of Arizona electrical engineers are 9 percent higher, than U.S. averages. But wages of aerospace engineers are 13 percent lower in Arizona than in the nation, and for electrical and electronics engineering technicians, Arizona wages are 7 percent lower.

### Exhibit 4.11: Comparing Arizona and U.S. Wages in Selected Detailed S&E Occupations, 2010

| Occ Code | Occ Title | Mean Annual AZ Wages | Mean Annual US Wages | Ratio of AZ to US Wages |
|---|---|---|---|---|
| **15-0000** | **Computer and Mathematical Occupations** | **$74,450** | **$77,230** | **96.4%** |
| 15-1121 | Computer Systems Analysts | 87,790 | 81,250 | 108.0 |
| 15-1131 | Computer Programmers | 74,420 | 74,900 | 99.4 |
| 15-1132 | Software Developers, Applications | 89,820 | 90,410 | 99.3 |
| 15-1133 | Software Developers, Systems Software | 95,280 | 97,960 | 97.3 |
| 15-1141 | Database Administrators | 68,230 | 75,730 | 90.1 |
| 15-1142 | Network and Computer Systems Administrators | 68,360 | 72,200 | 94.7 |
| 15-1150 | Computer Support Specialists | 48,240 | 49,930 | 96.6 |
| 15-1179 | Information Security Analysts, Web Developers, and Computer Network Architects | 70,530 | 79,370 | 112.5 |
| **17-0000** | **Architecture and Engineering Occupations** | **73,980** | **75,550** | **97.9** |
| 17-2011 | Aerospace Engineers | 86,540 | 99,000 | 87.4 |
| 17-2031 | Biomedical Engineers | 92,440 | 84,780 | 109.0 |
| 17-2041 | Chemical Engineers | 82,810 | 94,590 | 87.5 |
| 17-2061 | Computer Hardware Engineers | 91,370 | 101,600 | 89.9 |
| 17-2071 | Electrical Engineers | 95,440 | 87,770 | 108.7 |
| 17-2072 | Electronics Engineers | 93,330 | 92,730 | 100.6 |
| 17-2112 | Industrial Engineers | 92,940 | 78,450 | 118.5 |
| 17-2131 | Materials Engineers | 90,120 | 85,860 | 105.0 |
| 17-2141 | Mechanical Engineers | 78,370 | 82,480 | 95.0 |
| 17-3012 | Electrical and Electronics Drafters | 50,030 | 55,960 | 89.4 |
| 17-3013 | Mechanical Drafters | 51,370 | 51,200 | 100.3 |
| 17-3021 | Aerospace Engineering and Operations Technicians | 62,560 | 59,990 | 104.3 |
| 17-3023 | Electrical and Electronics Engineering Technicians | 52,730 | 56,690 | 93.0 |
| 17-3024 | Electro-Mechanical Technicians | 48,330 | 51,160 | 94.5 |
| 17-3026 | Industrial Engineering Technicians | 49,060 | 50,540 | 97.1 |
| 17-3027 | Mechanical Engineering | 50,560 | 51,450 | 98.3 |

| | | | | |
|---|---|---|---|---|
| | Technicians | | | |
| **19-0000** | **Life, Physical and Social Science Occupations** | **56,220** | **66,390** | **84.7** |
| 19-1021 | Biochemists and Biophysicists | 62,870 | 86,580 | 72.6 |
| 19-1022 | Microbiologists | 68,600 | 72,030 | 95.2 |
| 19-2031 | Chemists | 66,470 | 73,240 | 90.8 |
| 19-2032 | Materials Scientists | 89,080 | 86,300 | 103.2 |
| 19-4031 | Chemical Technicians | 41,760 | 44,200 | 94.5 |

***Source:*** *BLS, Occupational Employment Statistics*

Before drawing conclusions about relative labor scarcity from the data in Exhibit 4.11, two caveats should be noted. First, the nature of the jobs and the skills required to perform them may be different when comparing Arizona with the nation. This would certainly be true at the level of broad occupational groups. The average engineering job in Arizona may be very different from the average engineering job in the United States. An imperfect but useful adjustment for these differences can be made by using the detailed mix of jobs within a broad occupational group in Arizona to average the wages earned by U.S. workers in that same broad occupational group. Second, wages are an incomplete measure of the compensation or reward to working in a given region. In a perfectly integrated national labor market, wages may differ between states as an offset to differences in climate, other amenities, or cost of living. Wages have always been lower in Arizona than in the nation as a whole, and much of the difference is often attributed to a "sunshine factor," i.e., a general preference for living in a region with a dry and warm climate. Labor shortages at the state level for a given occupation group may manifest themselves not necessarily through wages that are higher in the state than in the nation, but in a state/national wage differential that is higher than the average differential across all occupations.

### Exhibit 4.12: Comparing Arizona and U.S. Wages, 2000

| Occ Code | Occ Title | Mean Annual AZ Wages | Mean Annual Adjusted US Wages* | Ratio of AZ to US Wages |
|---|---|---|---|---|
| 53-0000 | Transportation and Material Moving Occupations | $24,930 | $24,449 | 102.0% |
| 29-0000 | Healthcare Practitioners and Technical Occupations | 45,460 | 44,667 | 101.8 |
| **15-0000** | **Computer and Mathematical Occupations** | **56,990** | **57,271** | **99.5** |
| **17-0000** | **Architecture and Engineering Occupations** | **51,640** | **52,035** | **99.2** |
| 41-0000 | Sales and Related Occupations | 27,630 | 28,054 | 98.5 |
| 33-0000 | Protective Service Occupations | 30,380 | 31,288 | 97.1 |
| 49-0000 | Installation, Maintenance, and Repair Occupations | 32,340 | 33,340 | 97.0 |
| 39-0000 | Personal Care and Service Occupations | 18,800 | 19,483 | 96.5 |
| 35-0000 | Food Preparation and Serving Related Occupations | 15,250 | 15,820 | 96.4 |
| 31-0000 | Healthcare Support Occupations | 20,270 | 21,367 | 94.9 |
| 11-0000 | Management Occupations | 64,820 | 68,613 | 94.5 |

| | | | | |
|---|---|---|---|---|
| 43-0000 | Office and Administrative Support Occupations | 24,830 | 26,399 | 94.1 |
| 27-0000 | Arts, Design, Entertainment, Sports, and Media Occupations | 34,840 | 37,078 | 94.0 |
| 45-0000 | Farming, Fishing, and Forestry Occupations | 15,960 | 17,197 | 92.8 |
| 13-0000 | Business and Financial Operations Occupations | 45,230 | 48,985 | 92.3 |
| 51-0000 | Production Occupations | 24,640 | 26,689 | 92.3 |
| 21-0000 | Community and Social Service Occupations | 30,210 | 33,405 | 90.4 |
| 25-0000 | Education, Training, and Library Occupations | 33,360 | 37,597 | 88.7 |
| 23-0000 | Legal Occupations | 60,800 | 68,796 | 88.4 |
| **19-0000** | **Life, Physical, and Social Science Occupations** | **43,730** | **49,563** | **88.2** |
| 37-0000 | Building and Grounds Cleaning and Maintenance Occupations | 17,460 | 19,837 | 88.0 |
| 47-0000 | Construction and Extraction Occupations | 29,150 | 33,674 | 86.6 |
| | | | **Mean** | **94.2** |

***Note:*** *Adjusted to Arizona occupational mix.*
***Source:*** *BLS, Occupational Employment Statistics*

## Exhibit 4.13: Comparing Arizona and U.S. Wages, 2010

| Occ Code | Occ Title | Mean Annual AZ Wages | Mean Annual Adjusted US Wages* | Ratio of AZ to US Wages |
|---|---|---|---|---|
| 29-0000 | Healthcare Practitioners and Technical Occupations | $73,810 | $71,478 | 103.3% |
| 31-0000 | Healthcare Support Occupations | 27,580 | 27,048 | 102.0 |
| 35-0000 | Food Preparation and Serving Related Occupations | 21,380 | 21,248 | 100.6 |
| 53-0000 | Transportation and Material Moving Occupations | 33,890 | 33,782 | 100.3 |
| 39-0000 | Personal Care and Service Occupations | 24,450 | 24,588 | 99.4 |
| **17-0000** | **Architecture and Engineering Occupations** | **73,980** | **74,520** | **99.3** |
| 33-0000 | Protective Service Occupations | 43,900 | 44,680 | 98.3 |
| 43-0000 | Office and Administrative Support Occupations | 32,890 | 33,476 | 98.3 |
| **15-0000** | **Computer and Mathematical Occupations** | **74,450** | **76,241** | **97.7** |
| 49-0000 | Installation, Maintenance, and Repair Occupations | 41,420 | 42,485 | 97.5 |
| 51-0000 | Production Occupations | 32,750 | 33,635 | 97.4 |
| 41-0000 | Sales and Related Occupations | 35,650 | 36,921 | 96.6 |
| 37-0000 | Building and Grounds Cleaning and Maintenance Occupations | 23,900 | 25,432 | 94.0 |
| 27-0000 | Arts, Design, Entertainment, Sports, and Media Occupations | 45,220 | 48,423 | 93.4 |
| 45-0000 | Farming, Fishing, and Forestry Occupations | 19,790 | 21,434 | 92.3 |
| 21-0000 | Community and Social Service Occupations | 39,940 | 43,485 | 91.8 |
| **19-0000** | **Life, Physical, and Social Science Occupations** | **56,220** | **61,692** | **91.1** |
| 47-0000 | Construction and Extraction Occupations | 39,060 | 43,158 | 90.5 |

| | | | | |
|---|---|---|---|---|
| 11-0000 | Management Occupations | 93,000 | 103,272 | 90.1 |
| 13-0000 | Business and Financial Operations Occupations | 61,060 | 68,366 | 89.3 |
| 23-0000 | Legal Occupations | 83,100 | 95,025 | 87.5 |
| 25-0000 | Education, Training, and Library Occupations | 43,970 | 50,953 | 86.3 |
| | | | **Mean** | **95.3** |

***Note:*** *Adjusted to Arizona occupational mix.*
***Source:*** *BLS, Occupational Employment Statistics*

Exhibit 4.12 and Exhibit 4.13 provide a comparison of Arizona and U.S. wages that is more useful as an indicator of whether Arizona is experiencing or has experienced state-specific shortages of scientists and engineers. Data are presented for all 22 major occupational groups, not just the three relating to science and engineering. To adjust for differences in occupation mix, average U.S. wages for each major occupational group are calculated using the Arizona mix of detailed occupations. Data are presented for two years: 2000 and 2010. Not surprisingly, in each year average annual wages were lower in Arizona than they were in the nation, even after controlling for occupation mix. In 2000, the average ratio of Arizona wages to U.S. wages was 94.2 percent. In 2010, that ratio was 95.3 percent. Looking specifically at the three science and engineering occupational groups, the ratio of Arizona to U.S. wages was above average, at least for computer-related and engineering occupations. In 2000, the ratio of Arizona to U.S. wages in computer and mathematical occupations was 3rd highest among the 22 groups. The wage ratio for workers in architecture and engineering occupations was 4th highest. Neither of these ratios was above 100 percent, but each was significantly above the average across all occupations. In 2010, the ratios of Arizona wages to U.S. wages were again above average in computer-related and engineering occupations, but by a smaller margin. The ratio for architecture and engineering occupations was 6th highest among the 22 groups, and the ratio for computer and mathematical occupations was 9th highest. In both years, the ratio of Arizona to U.S. wages for workers in life, physical and social science occupations was well below the average across all occupations.

If wages are used as an indicator of labor scarcity, there is some evidence that Arizona may have faced greater shortages of scientists and engineers than was typical across the nation. This seems to have been truer in 2000 than in 2010. In 2000, the Arizona to U.S. wage differential in S&E occupations was approximately 5 percent higher than the average differential across all occupations. Any Arizona-specific shortages of S&E workers were limited to computer scientists and engineers. There is no indication that the state has faced shortages of workers in life, physical and social science occupations, outside of health care practitioners.

# 5 The Training of Scientists and Engineers in Arizona

## 5.1 Overview

In Chapter 3 it was noted that although U.S. science and engineering workers are highly mobile, creating a certain degree of integration in state and regional labor markets, it is also the case that there is a geographic persistence in people's location decisions. In particular, people who attend college in a state are much more likely to continue working and living in that state after they graduate than would be expected if geography were unimportant. Labor market conditions in a state are influenced by the supply of new graduates coming from local institutions. The purpose of this chapter is to provide information on the flow of new science and engineering graduates from institutions in Arizona and other states. The data are reviewed with an eye towards assessing whether Arizona technology companies might be handicapped in their recruiting of S&E workers by a low rate of production of new graduates in the state.

Section 5.2 provides information on the number of S&E degrees awarded at colleges and universities in Arizona and other states. Flows of new graduates are compared with the size of state populations. Salient findings from this section are as follows:

- The total number of science and engineering degrees awarded in Arizona has increased from 9,520 in 2000 to 12,370 in 2009. The rate of increase in degrees is roughly in line with the rate of growth in the state's population.

- When compared with the size of its population, Arizona produces relatively few science and engineering graduates. In 2000, Arizona accounted for 1.83 percent of the U.S. population but only 1.41 percent of the nation's S&E bachelor's degrees and 1.50 percent of the nation's graduate degrees. Since 2000, there has been a decline in the ratios of Arizona's degree shares to its population share. In 2009, Arizona accounted for 2.15 percent of the nation's population but only 1.51 percent of U.S. bachelor's degrees and 1.54 percent of U.S. graduate degrees.

- Looking at degrees by major field group, Arizona in 2009 accounted for 1.45 percent of U.S. degrees in computer science and mathematics, 1.78 percent of U.S. degrees in architecture and engineering, and 1.51 percent of U.S. degrees in life, physical or social science. Each of these percentages is significantly lower than the state's share of the national population.

- With the exception of Colorado and Utah, all Western states produce few S&E graduates when compared with the size of their populations. For example, in 2009 California accounted for 12.04 percent of the U.S. population but only 9.70 percent of U.S. graduates with degrees in computer science or mathematics. Even Washington, a major employer of computer scientists, produced 2.01 percent of the nation's graduates but had 2.17 percent of the nation's population. The results are similar for architecture and engineering graduates. Colorado and Utah are relatively large producers of these degrees. But in other Western states, production of architecture and engineering degrees is low relative to population size. For example, in 2009 California accounted for 10.54 percent of U.S. degrees in this area but had 12.04 percent of the nation's population.

Section 5.2.3 considers how Arizona's universities and community colleges connect students with degrees in computer science, engineering, science, and related fields to employers looking for employees with degrees in those fields. The report explores the range of services offered by career services; the way that career services departments are organized (and what that means for students and employers); how they promote hands-on experience; and the ways in which universities and businesses collaborate.

The report also discusses two innovative programs for community college students. One is an apprenticeship program designed to give both the hands-on experience as well as credentials that demonstrate a certain level of technical competency. The other is designed to train community college students to meet the needs of employers in emerging technology industries.

Section 5.3 considers Arizona's workforce development and training programs. There are several programs designed to help employees develop the skills they need to succeed in today's workforce; these programs could be a way to increase the availability of S&E labor to local technology companies. The report describes the services those programs offer, the kinds of people who use the services (and what they're looking for), and how the programs collaborate with employers.

In trying to assess whether local area firms are handicapped by a low supply of S&E graduates, it is more meaningful to benchmark the flow of new graduates in a state to the size of its S&E workforce instead of to the size of its resident population. Section 5.4 provides this kind of analysis for all U.S. states. Conclusions regarding adequacy of local supply are drawn by comparing the ratio of new graduates to workers in a state with the national average. The calculated ratios are indexed relative to the nation. An index value lower than 100 means that, when compared with the size of its S&E workforce, the flow of new S&E graduates in a state is below the national average. States with index values below 100 tend to be net importers of scientists and engineers, and companies located in these states tend to have a relatively difficult time recruiting S&E workers.

In 2000, Arizona produced relatively few science and engineering graduates in relation to the size of its S&E workforce. This was true for each of three broad groups of scientists and engineers. Index values in that year were 93 for computer scientists and mathematicians, 88 for architects and engineers, and 95 for all other scientists. Indexes measuring adequacy of local supply were also below 100 in almost all other Western states. In fact, for California, Colorado and Washington – Western states with especially large S&E employment – the indexed ratios of new graduates to employed workers were significantly lower than those for Arizona.

Results for 2009 indicate that flows of new S&E graduates in Arizona have declined further relative to the size of the local workforce. The state's index values for computer scientists and engineers have fallen into the low 80s. Index values for other Western states remain well below 100.

These results are consistent with a description of the Arizona job market in which local firms have a relatively hard time finding qualified science and engineering workers and must rely more than the average U.S. employer on S&E workers who have migrated to the state. In view of the success states such as California, Colorado and Washington have had in creating jobs for and recruiting S&E workers, it is clearly not necessary for a state to rely exclusively or even primarily on local colleges and universities to meet its S&E manpower needs. It is neither necessary nor economical, given the potential mobility of U.S. technology workers and the need to concentrate education centers, especially graduate programs, in a few states. Nevertheless, states that are relatively small producers of S&E graduates will be somewhat labor constrained, especially if they do not have a market area, climate or other amenities that make it easy to attract S&E workers from other states.

## 5.2 Colleges and Universities

A primary source of information on U.S. colleges and universities is the National Center for Education Statistics. Particularly useful for this report are statistics on the number of degrees awarded in Arizona and other states, broken out by field of study and type of degree. This information was collected for each year from 2000-2009 and for each U.S. state. To simplify the presentation and analysis, detailed fields of study in the areas of science and engineering were aggregated into three major groups, similar to the groups used to present BLS data on employment by occupation. Exhibit 5.1 shows the way in which individual fields were combined into three major groups: computer science and mathematics, architecture and engineering, and life, physical and social sciences. The data were also sorted into three types of degrees: associate, bachelor's and graduate (master's plus Ph.D.). Because the report is interested in the geographic residence of students receiving degrees, on-line degrees from the University of Phoenix were excluded from the figures for Arizona.

### Exhibit 5.1: Defining Major Fields of Science and Engineering Study

| |
|---|
| **Computer Science and Mathematics** |
| Computer and information sciences (11) |
| Mathematics and statistics (27) |
| **Architecture and Engineering** |
| Architecture (4) |
| Engineering (14) |
| Engineering technologies/technicians (15) |
| **Life, Physical and Social Sciences** |
| Agriculture and agricultural operations (1) |
| Agricultural sciences (2) |
| Natural resources (3) |
| Biological and biomedical sciences (26) |
| Physical sciences (40) |
| Science technologies/technicians (41) |
| Psychology (42) |
| Social sciences (45) |

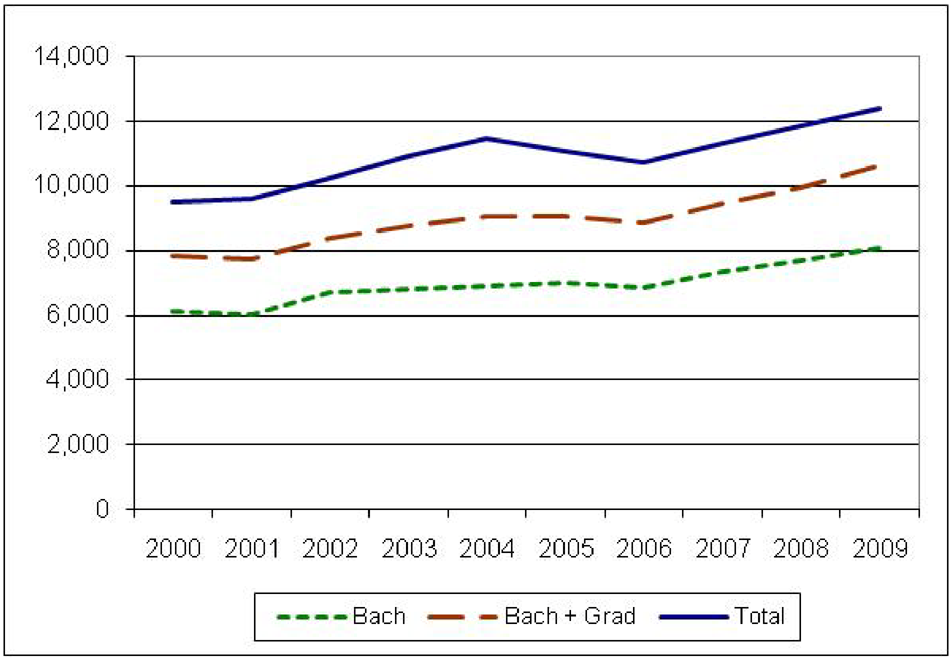
***Note:*** *Numbers in parentheses are CIP codes (Classification of Instructional Programs) used by the National Center for Education Statistics to classify programs of study at U.S. colleges and universities.*

### 5.2.1 Degrees from Arizona's Colleges and Universities, 2000-2009

The total number of science and engineering degrees awarded at Arizona's colleges and universities has increased almost continuously over the last decade, from 9,520 in 2000 to 12,370 in 2009. Much of the increase in higher education activity is attributable to population growth. Degrees produced in Arizona have increased at roughly the same pace (30 percent over the ten-year period) as the state's population (28 percent).

Exhibit 5.2 shows the growth in Arizona degrees by type of degree. Bachelor's degrees, which are by far the largest category of degrees, have increased by 32 percent, from 6,110 in 2000 to 8,090 in 2009. Graduate degrees have been the fastest growing category, increasing by 45 percent from 1,750 to 2,530. Associate degrees awarded in the state have increased only 6 percent over the ten-year period, from 1,660 to 1,760.

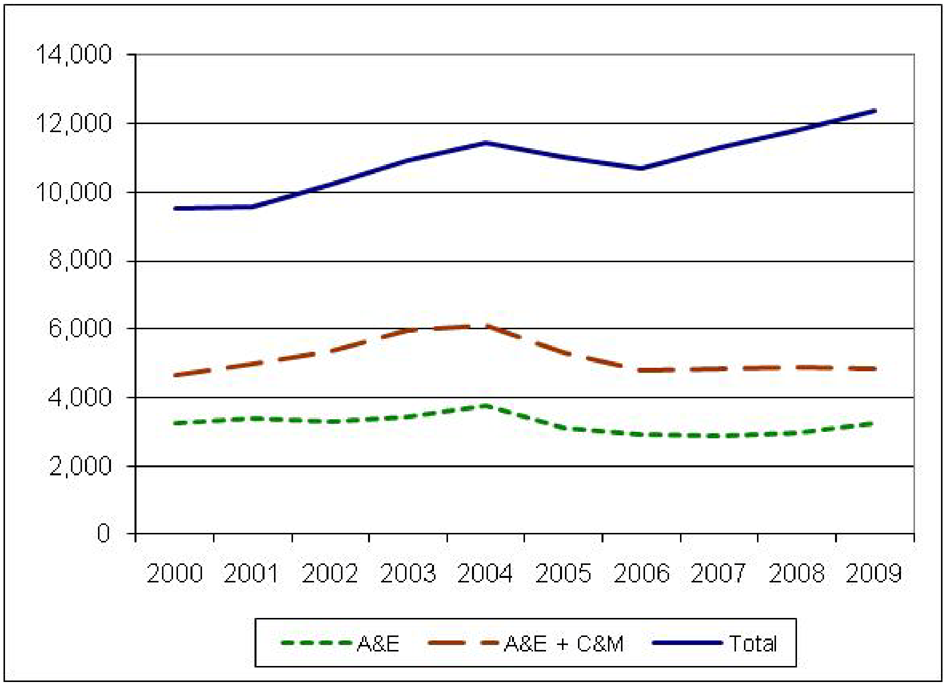
### Exhibit 5.2: Number of S&E Degrees from Arizona Colleges and Universities, by Type of Degree (2000-2009)




***Source:*** *National Center for Education Statistics, IPEDS*

Exhibit 5.3 shows the growth in Arizona degrees broken out by major field of study. The number of degrees awarded in architecture and engineering has scarcely changed over the period, totaling 3,230 in 2000 and 3,270 in 2009. As a share of all S&E degrees awarded in the state, architecture and engineering degrees have fallen from 34 percent to 26 percent. Degrees awarded in computer science and mathematics grew strongly from 2000 to 2003, but then began to fall off. If averaged over three-year periods, degrees in this area in the most recent period are only 6 percent higher than they were at the beginning of the period. The category of S&E degrees registering both the largest absolute and percentage growth is life, physical and social sciences. Degrees in this category have increased by 55 percent from 4,870 in 2000 to 7,550 in 2009. The share of total S&E degrees accounted for by the sciences has increased from 51 percent to 61 percent.

### Exhibit 5.3: Number of S&E Degrees from Arizona Colleges and Universities, by Major Field of Study (2000-2009)




***Source:*** *National Center for Education Statistics, IPEDS*

## 5.2.2 Comparing Arizona with Other States

Exhibit 5.4, Exhibit 5.5, Exhibit 5.6, and Exhibit 5.7 compare S&E degree production in Arizona with other U.S. states. For each state, the exhibits show degrees awarded as a percent of national totals. To assess the relative importance of degree production in a state, the exhibits also show a state's share of the U.S. population. Data are given for two years: 2000 and 2009. Exhibit 5.4 and Exhibit 5.5 combine all S&E fields and provide a breakdown by type of degree. Exhibit 5.6 and Exhibit 5.7 show totals for all types of degrees by major field of study.

### *5.2.2.1 By Type of Degree*

When compared with the size of its population, Arizona produces relatively few science and engineering graduates. In 2000, for example, Arizona accounted for 1.83 percent of the U.S. population but only 1.41 percent of the nation's S&E bachelor's degrees and 1.50 percent of the nation's graduate degrees. Since 2000, there has been a decline in the ratios of Arizona's degree shares to its population share. This means that while degrees in Arizona have increased at a slightly faster pace than its population, the margin of difference between growth in degrees and growth in the population has been even larger at the national level. In 2009, Arizona accounted for 2.15 percent of the nation's population and only 1.51 percent of U.S. bachelor's degrees and 1.54 percent of U.S. graduate degrees. Arizona started the decade as a relatively large producer of S&E associate degrees, with its share of the national total exceeding its share of the population. However, by 2009, its share of U.S. associate degrees had fallen short of its population share.

**Exhibit 5.4: Distribution of Science and Engineering Degrees Across U.S. States, by Type of Degree (Percent of U.S. Totals, 2000)**

| State | Associate's Degrees | Bachelor's Degrees | Graduate Degrees | Population |
|---|---|---|---|---|
| Alabama | 4.00 | 1.35 | 1.33 | 1.58 |
| Alaska | 0.14 | 0.10 | 0.13 | 0.22 |
| Arizona | 2.23 | 1.41 | 1.50 | 1.83 |
| Arkansas | 0.52 | 0.65 | 0.37 | 0.95 |
| California | 14.19 | 11.35 | 12.60 | 12.05 |
| Colorado | 1.11 | 2.24 | 2.52 | 1.53 |
| Connecticut | 0.57 | 1.34 | 1.56 | 1.21 |
| Delaware | 0.33 | 0.39 | 0.31 | 0.28 |
| D of C | 0.09 | 0.69 | 2.03 | 0.20 |
| Florida | 3.49 | 3.50 | 3.58 | 5.69 |
| Georgia | 0.64 | 2.27 | 2.29 | 2.92 |
| Hawaii | 0.56 | 0.39 | 0.43 | 0.43 |
| Idaho | 1.03 | 0.39 | 0.29 | 0.46 |
| Illinois | 2.02 | 4.09 | 5.55 | 4.41 |
| Indiana | 2.83 | 2.35 | 1.94 | 2.16 |
| Iowa | 1.22 | 1.43 | 0.94 | 1.04 |
| Kansas | 1.46 | 1.11 | 1.02 | 0.95 |
| Kentucky | 1.06 | 1.13 | 0.77 | 1.43 |
| Louisiana | 0.99 | 1.49 | 1.18 | 1.58 |
| Maine | 0.28 | 0.52 | 0.15 | 0.45 |
| Maryland | 0.53 | 2.08 | 2.86 | 1.88 |
| Massachusetts | 2.16 | 3.98 | 5.34 | 2.26 |
| Michigan | 2.94 | 3.55 | 4.00 | 3.53 |
| Minnesota | 0.93 | 1.84 | 1.34 | 1.75 |
| Mississippi | 0.96 | 0.75 | 0.57 | 1.01 |
| Missouri | 2.18 | 2.08 | 2.32 | 1.99 |
| Montana | 0.38 | 0.47 | 0.34 | 0.32 |
| Nebraska | 1.15 | 0.71 | 0.56 | 0.61 |
| Nevada | 0.32 | 0.26 | 0.26 | 0.72 |
| New Hampshire | 0.60 | 0.67 | 0.43 | 0.44 |
| New Jersey | 1.91 | 2.68 | 2.49 | 2.99 |
| New Mexico | 0.81 | 0.50 | 0.62 | 0.65 |
| New York | 8.50 | 7.82 | 8.81 | 6.73 |
| North Carolina | 2.01 | 3.00 | 2.29 | 2.86 |
| North Dakota | 0.43 | 0.35 | 0.17 | 0.23 |
| Ohio | 5.16 | 3.61 | 3.73 | 4.03 |
| Oklahoma | 1.56 | 1.06 | 1.61 | 1.22 |
| Oregon | 1.38 | 1.37 | 0.95 | 1.22 |
| Pennsylvania | 5.70 | 5.32 | 4.40 | 4.35 |
| Rhode Island | 0.78 | 0.66 | 0.48 | 0.37 |
| South Carolina | 1.23 | 1.31 | 0.88 | 1.43 |
| South Dakota | 0.40 | 0.39 | 0.22 | 0.27 |
| Tennessee | 1.51 | 1.71 | 1.29 | 2.02 |

| | | | | |
|---|---|---|---|---|
| Texas | 7.66 | 5.73 | 6.11 | 7.42 |
| Utah | 1.18 | 1.31 | 0.82 | 0.80 |
| Vermont | 0.40 | 0.46 | 0.22 | 0.22 |
| Virginia | 3.11 | 3.16 | 2.81 | 2.52 |
| Washington | 2.32 | 2.00 | 1.48 | 2.09 |
| West Virginia | 0.62 | 0.58 | 0.45 | 0.64 |
| Wisconsin | 2.03 | 2.21 | 1.48 | 1.90 |
| Wyoming | 0.41 | 0.17 | 0.18 | 0.18 |

***Source:*** *National Center for Education Statistics, IPEDS*

### Exhibit 5.5: Distribution of Science and Engineering Degrees Across U.S. States, by Type of Degree (Percent of U.S. Totals, 2009)

| State | Associate's Degrees | Bachelor's Degrees | Graduate Degrees | Population |
|---|---|---|---|---|
| Alabama | 4.85% | 1.28% | 1.29% | 1.53% |
| Alaska | 0.15 | 0.12 | 0.13 | 0.23 |
| Arizona | 1.98 | 1.51 | 1.54 | 2.15 |
| Arkansas | 0.51 | 0.61 | 0.38 | 0.94 |
| California | 14.91 | 12.01 | 12.98 | 12.04 |
| Colorado | 1.10 | 2.16 | 2.12 | 1.64 |
| Connecticut | 0.43 | 1.36 | 1.75 | 1.15 |
| Delaware | 0.21 | 0.31 | 0.31 | 0.29 |
| D of C | 0.12 | 0.87 | 1.88 | 0.20 |
| Florida | 3.62 | 4.36 | 3.99 | 6.04 |
| Georgia | 1.50 | 2.41 | 2.53 | 3.20 |
| Hawaii | 0.41 | 0.35 | 0.33 | 0.42 |
| Idaho | 0.48 | 0.50 | 0.29 | 0.50 |
| Illinois | 2.45 | 4.01 | 5.56 | 4.21 |
| Indiana | 2.42 | 2.14 | 1.73 | 2.09 |
| Iowa | 1.66 | 1.49 | 0.83 | 0.98 |
| Kansas | 0.76 | 0.96 | 0.94 | 0.92 |
| Kentucky | 1.10 | 1.07 | 0.95 | 1.41 |
| Louisiana | 1.13 | 1.25 | 0.90 | 1.46 |
| Maine | 0.24 | 0.52 | 0.12 | 0.43 |
| Maryland | 1.04 | 2.23 | 3.05 | 1.86 |
| Massachusetts | 1.65 | 3.67 | 4.86 | 2.15 |
| Michigan | 4.28 | 3.38 | 3.64 | 3.25 |
| Minnesota | 1.89 | 1.96 | 2.02 | 1.72 |
| Mississippi | 1.00 | 0.66 | 0.57 | 0.96 |
| Missouri | 1.94 | 2.03 | 2.10 | 1.95 |
| Montana | 0.24 | 0.41 | 0.27 | 0.32 |
| Nebraska | 0.95 | 0.66 | 0.62 | 0.59 |
| Nevada | 0.67 | 0.36 | 0.34 | 0.86 |
| New Hampshire | 0.40 | 0.58 | 0.45 | 0.43 |
| New Jersey | 1.65 | 2.46 | 2.38 | 2.84 |
| New Mexico | 0.61 | 0.46 | 0.60 | 0.65 |
| New York | 5.63 | 8.04 | 9.12 | 6.37 |

| | | | | |
|---|---|---|---|---|
| North Carolina | 2.43 | 2.97 | 2.36 | 3.06 |
| North Dakota | 0.52 | 0.28 | 0.21 | 0.21 |
| Ohio | 5.13 | 3.36 | 3.27 | 3.76 |
| Oklahoma | 1.97 | 1.01 | 0.88 | 1.20 |
| Oregon | 0.80 | 1.27 | 0.88 | 1.25 |
| Pennsylvania | 4.77 | 5.36 | 4.76 | 4.11 |
| Rhode Island | 0.62 | 0.61 | 0.47 | 0.34 |
| South Carolina | 0.92 | 1.29 | 0.71 | 1.49 |
| South Dakota | 0.39 | 0.34 | 0.23 | 0.26 |
| Tennessee | 1.44 | 1.55 | 1.17 | 2.05 |
| Texas | 7.71 | 5.95 | 6.61 | 8.07 |
| Utah | 1.07 | 1.32 | 0.76 | 0.91 |
| Vermont | 0.17 | 0.45 | 0.54 | 0.20 |
| Virginia | 4.53 | 3.10 | 3.19 | 2.57 |
| Washington | 2.35 | 2.05 | 1.43 | 2.17 |
| West Virginia | 0.49 | 0.59 | 0.48 | 0.59 |
| Wisconsin | 2.21 | 2.16 | 1.37 | 1.84 |
| Wyoming | 0.47 | 0.13 | 0.10 | 0.18 |

***Source:*** *National Center for Education Statistics, IPEDS*

Looking at other Western states, Nevada and New Mexico also produce relatively few S&E graduates, measured again by comparing their shares of national degree totals with their shares of the U.S. population. Colorado produces a relatively large number of S&E graduates. Utah is a large producer of S&E graduates with bachelor's degrees. New S&E graduates in California are roughly proportional to the state's share of the U.S. population. Production of S&E bachelor's degrees in Oregon and Washington are also proportional to their population. Their shares of U.S. S&E graduate degrees, however, are relatively small.

On a national level, states with shares of U.S. S&E bachelor's degrees that are larger than their shares of the U.S. population include Massachusetts, New York and Pennsylvania. States with relatively large shares of U.S. graduate degrees include Illinois, Maryland, Massachusetts and New York. Notable states with relatively low production of S&E graduates, both bachelor's and graduate, are Florida, Georgia and Texas.

#### 5.2.2.2 By Field of Study

Exhibit 5.6 and Exhibit 5.7 show whether a state is a large or small producer of degrees in a particular field of science or engineering. When compared with the size of its population, Arizona is seen to produce relatively few graduates with degrees in computer science and mathematics and relatively few with degrees in the life, physical and social sciences. In both of the years shown, Arizona's shares of national degree totals in these field groups were less than its population share. Looking at computer science and mathematics, Arizona in 2000 accounted for 1.83 percent of the national population but only 1.65 percent of national degree totals. Since 2000, the ratio of Arizona's share of degrees to its population share has fallen. In 2009, Arizona accounted for 2.15 percent of the U.S. population but only 1.45 percent of all U.S. graduates with degrees in computer science or mathematics. Arizona's production of graduates in the life, physical and social sciences is also disproportionately small when compared to its population. In 2009, for example, the state accounted for only 1.51 percent of national degrees in this field group.

### Exhibit 5.6: Distribution of Science and Engineering Degrees Across U.S. States, by Major Field of Study (Percent of U.S. Totals, 2000)

| State | Computer Science and Mathematics | Architecture and Engineering | Life, Physical and Social Sciences | Population |
|---|---|---|---|---|
| Alabama | 1.67% | 2.73% | 1.24% | 1.58% |
| Alaska | 0.06 | 0.15 | 0.11 | 0.22 |
| Arizona | 1.65 | 2.09 | 1.27 | 1.83 |
| Arkansas | 0.68 | 0.44 | 0.62 | 0.95 |
| California | 10.93 | 10.18 | 12.84 | 12.05 |
| Colorado | 2.14 | 2.12 | 2.18 | 1.53 |
| Connecticut | 0.94 | 0.84 | 1.55 | 1.21 |
| Delaware | 0.29 | 0.27 | 0.43 | 0.28 |
| D of C | 0.96 | 0.47 | 1.01 | 0.20 |
| Florida | 3.67 | 4.16 | 3.22 | 5.69 |
| Georgia | 2.76 | 2.03 | 1.94 | 2.92 |
| Hawaii | 0.59 | 0.33 | 0.41 | 0.43 |
| Idaho | 0.30 | 0.46 | 0.47 | 0.46 |
| Illinois | 4.10 | 4.08 | 4.14 | 4.41 |
| Indiana | 2.26 | 3.35 | 1.94 | 2.16 |
| Iowa | 1.05 | 1.26 | 1.40 | 1.04 |
| Kansas | 0.99 | 1.08 | 1.19 | 0.95 |
| Kentucky | 0.93 | 1.03 | 1.10 | 1.43 |
| Louisiana | 1.28 | 1.45 | 1.36 | 1.58 |
| Maine | 0.21 | 0.28 | 0.53 | 0.45 |
| Maryland | 2.59 | 1.48 | 2.15 | 1.88 |
| Massachusetts | 3.54 | 3.90 | 4.18 | 2.26 |
| Michigan | 2.66 | 5.54 | 2.97 | 3.53 |
| Minnesota | 1.56 | 1.36 | 1.77 | 1.75 |
| Mississippi | 0.66 | 0.79 | 0.75 | 1.01 |
| Missouri | 2.29 | 2.15 | 2.10 | 1.99 |
| Montana | 0.38 | 0.45 | 0.44 | 0.32 |
| Nebraska | 0.89 | 0.55 | 0.77 | 0.61 |
| Nevada | 0.19 | 0.31 | 0.27 | 0.72 |
| New Hampshire | 0.70 | 0.31 | 0.72 | 0.44 |
| New Jersey | 3.21 | 1.82 | 2.69 | 2.99 |
| New Mexico | 0.52 | 0.79 | 0.47 | 0.65 |
| New York | 11.35 | 6.55 | 7.97 | 6.73 |
| North Carolina | 2.03 | 2.43 | 3.04 | 2.86 |
| North Dakota | 0.23 | 0.50 | 0.28 | 0.23 |
| Ohio | 3.58 | 4.86 | 3.46 | 4.03 |
| Oklahoma | 0.95 | 1.18 | 1.30 | 1.22 |
| Oregon | 0.83 | 1.22 | 1.43 | 1.22 |
| Pennsylvania | 5.46 | 5.63 | 4.96 | 4.35 |
| Rhode Island | 0.83 | 0.62 | 0.60 | 0.37 |
| South Carolina | 1.25 | 0.98 | 1.31 | 1.43 |
| South Dakota | 0.35 | 0.36 | 0.36 | 0.27 |

| | | | | |
|---|---|---|---|---|
| Tennessee | 1.17 | 1.67 | 1.69 | 2.02 |
| Texas | 6.78 | 6.65 | 5.61 | 7.42 |
| Utah | 1.43 | 1.08 | 1.20 | 0.80 |
| Vermont | 0.23 | 0.21 | 0.53 | 0.22 |
| Virginia | 3.06 | 2.75 | 3.23 | 2.52 |
| Washington | 1.73 | 1.91 | 2.00 | 2.09 |
| West Virginia | 0.37 | 0.69 | 0.55 | 0.64 |
| Wisconsin | 1.62 | 2.27 | 2.06 | 1.90 |
| Wyoming | 0.13 | 0.18 | 0.23 | 0.18 |

***Source:*** *National Center for Education Statistics, IPEDS*

### Exhibit 5.7: Distribution of Science and Engineering Degrees Across U.S. States, by Major Field of Study (Percent of U.S. totals, 2009)

| State | Computer Science and Mathematics | Architecture and Engineering | Life, Physical and Social Sciences | Populatio n |
|---|---|---|---|---|
| Alabama | 2.20% | 2.63% | 1.23% | 1.53% |
| Alaska | 0.07 | 0.16 | 0.12 | 0.23 |
| Arizona* | 1.45 | 1.78 | 1.51 | 2.15 |
| Arkansas | 0.61 | 0.47 | 0.57 | 0.94 |
| California | 9.70 | 10.54 | 13.88 | 12.04 |
| Colorado | 2.15 | 2.13 | 1.97 | 1.64 |
| Connecticut | 0.87 | 1.20 | 1.49 | 1.15 |
| Delaware | 0.25 | 0.26 | 0.33 | 0.29 |
| D of C | 1.16 | 0.57 | 1.12 | 0.20 |
| Florida | 4.32 | 4.63 | 4.02 | 6.04 |
| Georgia | 2.83 | 2.42 | 2.19 | 3.20 |
| Hawaii | 0.32 | 0.28 | 0.39 | 0.42 |
| Idaho | 0.38 | 0.47 | 0.47 | 0.50 |
| Illinois | 5.80 | 3.71 | 3.97 | 4.21 |
| Indiana | 1.98 | 3.05 | 1.75 | 2.09 |
| Iowa | 1.61 | 1.16 | 1.39 | 0.98 |
| Kansas | 0.73 | 1.05 | 0.93 | 0.92 |
| Kentucky | 1.01 | 1.01 | 1.07 | 1.41 |
| Louisiana | 0.92 | 1.42 | 1.13 | 1.46 |
| Maine | 0.15 | 0.31 | 0.49 | 0.43 |
| Maryland | 3.28 | 1.75 | 2.24 | 1.86 |
| Massachusetts | 3.21 | 3.54 | 3.85 | 2.15 |
| Michigan | 3.61 | 5.24 | 2.89 | 3.25 |
| Minnesota | 2.19 | 1.51 | 2.08 | 1.72 |
| Mississippi | 0.50 | 0.72 | 0.70 | 0.96 |
| Missouri | 2.30 | 1.97 | 2.00 | 1.95 |
| Montana | 0.24 | 0.41 | 0.37 | 0.32 |
| Nebraska | 0.80 | 0.59 | 0.69 | 0.59 |
| Nevada | 0.38 | 0.38 | 0.40 | 0.86 |
| New Hampshire | 0.41 | 0.39 | 0.61 | 0.43 |
| New Jersey | 2.26 | 2.11 | 2.47 | 2.84 |

| | | | | |
|---|---|---|---|---|
| New Mexico | 0.57 | 0.65 | 0.43 | 0.65 |
| New York | 8.95 | 7.05 | 8.14 | 6.37 |
| North Carolina | 2.58 | 2.56 | 2.91 | 3.06 |
| North Dakota | 0.25 | 0.51 | 0.22 | 0.21 |
| Ohio | 3.59 | 4.42 | 3.20 | 3.76 |
| Oklahoma | 0.85 | 1.29 | 1.07 | 1.20 |
| Oregon | 0.92 | 0.97 | 1.24 | 1.25 |
| Pennsylvania | 6.16 | 5.51 | 4.84 | 4.11 |
| Rhode Island | 0.66 | 0.61 | 0.56 | 0.34 |
| South Carolina | 0.97 | 0.85 | 1.26 | 1.49 |
| South Dakota | 0.31 | 0.37 | 0.31 | 0.26 |
| Tennessee | 1.29 | 1.37 | 1.52 | 2.05 |
| Texas | 5.58 | 7.14 | 6.11 | 8.07 |
| Utah | 1.38 | 1.07 | 1.17 | 0.91 |
| Vermont | 0.37 | 0.21 | 0.54 | 0.20 |
| Virginia | 3.55 | 3.26 | 3.22 | 2.57 |
| Washington | 2.01 | 1.68 | 2.05 | 2.17 |
| West Virginia | 0.40 | 0.52 | 0.60 | 0.59 |
| Wisconsin | 1.85 | 1.90 | 2.07 | 1.84 |
| Wyoming | 0.09 | 0.17 | 0.18 | 0.18 |

***Source:*** *National Center for Education Statistics, IPEDS*

Looking at degrees in architecture and engineering, Arizona started the period as a relatively large producer, but finished as a small producer. As shown in Exhibit 5.3, Arizona degrees awarded in architecture and engineering increased significantly from 2000-2004 but then began to decline. By 2009 Arizona degrees in this field group were essentially at the same absolute level as they were in 2000. All the while, the annual number of U.S. graduates increased, and the state's share of the national population also increased. By 2009, Arizona accounted for 1.78 percent of U.S. degrees in architecture and engineering but 2.15 percent of the U.S. population.

Examining degrees in computer science and mathematics in other Western states, all states expect Colorado and Utah are seen to produce relatively few graduates in comparison with the size of their populations. California in 2009, for example, accounted 12.04 percent of the U.S. population but only 9.70 percent of U.S. graduates with degrees in computer science or mathematics. Even Washington, a major employer of computer scientists, produced 2.01 percent of the nation's graduates while accounting for 2.17 percent of the nation's population.

Results for architecture and engineering graduates in Western states are similar to those for graduates with degrees in computer science and mathematics. Colorado and Utah are relatively large producers of these degrees. Production of architecture and engineering degrees in New Mexico is essentially proportional to its population size. In all other Western states, production of architecture and engineering degrees is low relative population size. California, for example, accounted for 10.54 percent of all U.S. degrees in this field group but had 12.04 percent of the nation's population.

With regard to the life, physical and social sciences, California, Colorado and Utah all graduate a disproportionately large number of graduates. Oregon and Washington produce degrees in this field group that are roughly commensurate with their populations. Nevada and New Mexico are relative small producers of science graduates.

Looking at the rest of the nation, states that are relatively large producers of computer science and mathematics graduates include Illinois, Massachusetts, New York, Pennsylvania and Virginia. Large states that produce relatively few of these degrees include Florida, New Jersey and Texas. States that are relatively large producers of graduates with degrees in architecture and engineering include Indiana, Massachusetts, Michigan, Pennsylvania and Virginia. States producing relatively few of graduates in this area include Florida, Georgia and New Jersey. Looking at degrees in the life, physical and social sciences, states that produce a relatively large number of graduates include Massachusetts, New York, Pennsylvania and Virginia. Large states that produce relatively few degrees in this field group are Florida, Georgia and Texas.

Given the high mobility of U.S. technology workers and the need to concentrate education centers, especially graduate programs, in a few states, it is neither necessary nor economical for states to strive for parity between their production of science and engineering graduates and their shares of the national population. Nevertheless, states that are relatively small producers of S&E graduates will be somewhat labor constrained, especially if they do not have a market area, climate or other amenities that make it easy to attract graduates from other states. Before suggesting that Arizona or other states may be handicapped by the flow of their local graduates, it is important to sharpen the analysis by comparing degrees produced in a state with the size of its local S&E workforce, rather than with the size of its population. This will be done in Section 5.4.

### 5.2.3 How Do Universities and Colleges Connect Graduates with Employers?

Chapter 6 considers in depth at how Arizona's technology employers source their talent. This section asks similar questions of the people sitting on the other side of the table – of the suppliers of technology talent in Arizona. How do universities and community colleges connect students with degrees in computer science, engineering, science, and related fields to employers looking for employees with degrees in those fields?

To find the answers to those questions, individuals involved with career services at Arizona State University, University of Arizona, Northern Arizona University, and Maricopa Community Colleges were interviewed.

#### 5.2.3.1 Universities

Arizona's three public universities all have career services offices that work to help students find internships and, ultimately, jobs. All three offer a range of services, including:

- **Career fairs.** These are the large events where companies set up tables and students walk around the room to meet prospective employers. Typically, the university charges employers a fee to participate. All three universities host university-wide career fairs as well as separate, smaller fairs focused on STEM (science, technology, engineering, and math) students and employers.
- **Career mixers.** These are smaller, "more intimate" events. There is typically not a fee to attend these mixers, which are designed to give students, faculty, alumni, and employers a chance to network. Most are hosted by departments within the university (e.g. Civil Engineering).
- **Online job and résumé database.** All three universities have a database that allows students to search jobs and post résumés; and businesses to post jobs and search résumés. Ira A. Fulton Schools of Engineering at ASU recently added a new feature for students to list specific kinds of skills and experience as "attributes" that companies can search. The tool

lets employers drill down beyond basic criteria like major and year – a powerful tool given how important specific skills sets and specific kinds of experience are to employers (see Section 6.3) .

- **On-campus recruiting.** All three universities host employers who come on campus to recruit students. In many cases, employers will invite particular students they've found through the online database to interview.
- **Career development.** All three universities also work with students to prepare for a career in a given field. That often involves preparing for the interview process (mock interviews, résumé preparation, helping students understand how to work career fairs and networking events). It also involves "career education" – understand what a career in a certain field might be like. In many cases, the universities rely on businesses for career preparation help and to offer students a glimpse into what working in a certain type of job is like.

**Centralized/decentralized career services.** At all three universities there is a centralized career services office that serves students across all programs and disciplines. But at ASU and NAU there are also "decentralized" career services organizations that specifically serve technology-related programs. At ASU, for example, the Ira A. Fulton Schools of Engineering have their own career services office. Before the office was created, employers said that it was difficult to "work through the main career services office and organizational silos" to find technical talent. Now, employers report that the process is much more efficient, which yields them a better ROI.

While the University of Arizona doesn't have a decentralized career services office within the STEM-related departments, they operate on a "liaison" model rather than a "generalist" model, which means that advisors from the main career services office are assigned to particular colleges. Engineering and science liaisons, then, can develop deep knowledge and expertise in STEM-related industries and relationships with the employers in those industries. The liaison to the engineering departments also helps those students with professional development, including working with students on résumé preparation, how to work a career fair event, how to network.

**Internships and other hands-on experiences.** While the ultimate goal of career services is of course to connect students with employment once they've graduated, there is an increasingly strong focus on work and internship opportunities during the students' schooling as well. Junior- and senior-year internships have existed for a long time; now the universities are promoting first- and second-year internships as well. They are working with employers to understand that internships can be a "strategic" pipeline for talent (see Section 6.3.4.1 for the employers' perspective).

"We want companies to be thinking about how they can engage students early on. We help companies, especially the smaller ones who are a bit less sophisticated about these things, understand that the top students are doing internships, so if employers want those top students they need to look at internships as a strategic pipeline for hiring recent graduates."[50] What's more, internships are an opportunity for both the student and the employer to "test drive" the relationship.

On the other side, career services personnel are working with students to help them understand the importance of hands-on experience as a job qualification. At ASU Ira A. Fulton Schools of

[50] Quotations in this sub-section come from interviews with career services personnel at the state's three public universities.

Engineering there is the Fulton Undergraduate Research Initiative (FURI) and Engineering Projects In Community Service (EPICS), both designed to offer students "real world" hands-on experience as part of their education. "So it's not only about traditional kinds of hands-on experience like internships but alternative routes to experience, too." Northern Arizona University calls it "experiential learning," a concept that has been buzzing around campus, even more so among engineering students and faculty who talk a lot about the importance of a hands-on approach.

**University-industry collaboration.** In addition to the kinds of career services described above (career fairs and mixers, on-campus recruiting events, online databases), all of the universities also reported collaboration directly with businesses. ASU Ira A. Fulton Schools of Engineering career services personnel, for example, first meet with the employer and use a consulting-like approach to determine what the employer's needs are. Then, they put the company on a "roadmap for engagement" – which might include job shadowing, capstone courses, and internships, in addition to attendance at the career events.

NAU has a Computer Information Systems (CIS) advisory board made up of Arizona employers who discuss the curricula and make recommendations for changes (for example, adding SAP into the coursework). Across all three universities, much of that kind of program-level collaboration – including collaboration on curriculum development and capstone courses – happens between businesses and faculty (in addition to, or rather than, at career services).

All three universities talked about having recently created positions for personnel who would liaise directly with businesses. The centralized career services office at ASU just created an assistant director of employer relations and outreach position to meet with academic units and connect students with employers. U of A has a full-time director of employer relations who works in Phoenix to cultivate strategic partnerships with the metro Phoenix alumni association, do face-to-face meetings with employers, and engage with industry professional associations.

**Marketing their services.** A number of the career services personnel who were interviewed talked about having difficulty in getting the word out to businesses about all of the services they offer. Many said that they have a hard time engaging with employers who don't come to them directly.

The career services personnel have a somewhat easier time marketing to students, but it's a concerted effort. At the U of A, students use the career services website from Day 1 as a portal for any kind of on-campus or off-campus employment or internship opportunity. Career services personnel also connect with academic advisors as a route to connect with students.

At the U of A, part of the admissions process for engineering students is to register with the career services website. "That was in response to employer feedback; they wanted to ensure that students were aware of especially the internship and summer job opportunities that were available."

#### 5.2.3.2 Community Colleges

The community colleges in Arizona provide some of the same career services as the three public universities do – including, most notably, career fairs. But in other ways, the work they do to connect students with employers is quite different, because kinds of students they graduate and the kinds of skills they teach are different. Some community college students go on to a four-year program after graduating with an associate's degree, but many go to work in industry at the technician level.

In terms of actually matching students with employers, the Maricopa Community Colleges largely rely on the Maricopa Career Network. Provided in partnership with Jobing.com, the Career Network is a web-based listing of employment opportunities throughout the Phoenix area. It works much the same way any online job board does – students can post their résumés and search jobs and employers can search résumés and post jobs.

The Maricopa Community Colleges workforce development focus is more significantly on working to understand where the job demand will be in the future, and connecting colleges to that demand by creating programs to train students for work in those jobs. (And then marketing those programs to students.) For example, there are a number of warehouse and distribution companies that have located in Mesa so Mesa Community College at Red Mountain developed a program to train students for jobs in warehousing and distribution. The community colleges also work with economic development agencies to understand the key strategic industries they're targeting so the colleges can train workers to meet firms' demand in those industries.

In terms of the kinds of programs offered, hands-on experience is also a focus. The interviewees from Maricopa Community Colleges said that they are hearing, more so now than in the past, that graduates don't have the kinds of hands-on experience necessary to develop technical competency. In response, they are designing an apprenticeship program that will give both the hands-on experience as well as credentials that demonstrate a certain level of technical competency. Currently, they're working with the precision machining aerospace sector to develop that apprenticeship program. The program is designed to offer businesses what they say they've been lacking:

- Certifications provide more assurance to the employer about the student's technical competencies in safety, quality, and measurement – "so it's not a guessing game"
- With the certifications and hands-on experience, students are valuable (productive) to the employer right away
- The apprenticeship program will provide a local supply of technicians so employers don't have to recruit from out of state

The program works like this: before going to work in a business, the student does a pre-apprenticeship program that gives him or her industry-recognized credentials (which help the company feel more comfortable with regard to the student's understanding of quality and safety). Then, the student goes to work in an entry-level position as an apprentice with the company.

There are also a number of innovative programs designed to train community college students to meet the needs of employers in emerging technology industries. The Advanced Technological Education (ATE) program is one example. Funded by the National Science Foundation, the ATE is designed to support community colleges in educating their students in "cutting-edge" industries. ATE "prepares technicians for the high-technology workplaces that the U.S. needs to prosper."[51]

There are 39 ATE centers around the country in seven key technology areas, including microelectronics and nanotechnologies, which is the focus of the Maricopa Advanced Technology Education Center (MATEC), hosted the Maricopa County Community Colleges. The program is

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[51] Quotations in this sub-section come from a meeting with five individuals involved with the Maricopa Advanced Technology Education Center: Matt Kim, Ray Tsui, Rick Hansen, Tom McGlew, and Trevor Thornton.

modeled after the National Center for Nanotechnology Applications and Career Knowledge (NACK), which is hosted by Pennsylvania State University.

Most broadly, NACK supports the development and enrichment of 2-year degree programs in microelectronics and nanotechnology across the nation. Its key offerings include hands-on and real-time remote access to state-of-the-art clean room equipment for teaching via the Internet – to give students the kind of hands-on "real world" experience that firms say they're looking for (see Section 6.3.4). "Students get hired right away out of this program because it gives them working knowledge of actual tools."

In Arizona, members of the Az Nanotech Cluster, Maricopa Community Colleges, and Arizona State University are working with Pennsylvania State University (PSU) to design a program to bring NACK resources to Arizona students. Some of the options being considered include sending Arizona students to spend a semester at PSU in capstone courses, at the end of which they get a certification that will make them more marketable for microelectronics and nanotechnology jobs.

That "six-pack" capstone semester is not likely to be in Arizona course catalogs in the near future, though, as there isn't a lot of demand (that businesses have articulated anyway) for students with nanotechnology skill sets and experience. "Of course, it's a chicken-or-the-egg issue. Some businesses in this field may not come to Arizona because of a lack of local talent."

A more viable short-term option may be for Arizona community college professors to incorporate NACK materials into their lectures, as well as NACK-designed lab courses either at the local university (e.g., ASU NanoFab) or at the community college via remote web access to PSU equipment or simply by video. "For now, we're focusing on infusing nanotechnology content into current courses." The ASU NanoFab, operated by the Center for Solid State Electronics Research at ASU Fulton Schools of Engineering, offers hands-on real-time and remote access to give students as well as community college faculty exposure to these emerging technologies, which they can then incorporate into their own coursework.

While Maricopa Advanced Technology Education Center (MATEC) is certainly not the only Arizona example of university-community college collaboration, it offers an interesting look into how they are working to position themselves for the next "big" technology. "From solar to semiconductors to biotechnology, nanotech is an enabling technology used by many industries." For that reason, even as industries change, the education should remain relevant.

Part of the value that Maricopa Advanced Technology Education Center (MATEC) is working to offer is a general, across-the-board understanding of key concepts. "Employers need people who understand the basics of microelectronics and nanotechnology, including at the technician level. In a place like Silicon Valley there are lots of people with no four-year degree who understand the concepts simply because of osmosis – because the opportunities to absorb them are everywhere."

## 5.3 Workforce Development and Training Programs[52]

There are several programs in Arizona designed to help employees develop the skills they need to succeed in today's workforce. Though it's certainly not a driver of their efforts, these programs

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[52] Unless otherwise noted, quotations in this sub-section come from interviews with four individuals involved in workforce development and training: Diana Shepherd, Kirsten Hall, Mary Wolf Francis, and Rosalyn Boxer.

could be a way to increase the availability of S&E labor to local technology companies. Here, the report describes the services those programs offer, the kinds of people who use the services (and what they're looking for), and how the programs collaborate with employers. For employers' perspective on workforce development and training programs as a source of technology talent, see Section 6.4.7.

### 5.3.1 One-Stop Service Centers

Most (though not all) of these programs fall under the auspices of the Workforce Investment Act of 1998. "A main feature of Title I of the Workforce Investment Act (WIA) of 1998 is the creation of a One-Stop customer delivery system. Through this system, customers can access a broad range of employment-related and training services at a single point-of-entry."[53]

A list of fifteen kinds of workforce development and training programs – from services for dislocated workers (most relevant to the report's discussion) to veterans employment and training to senior community service employment – must now deliver their services through this single point of entry, called One-Stop service centers.[54] There are broadly two types of One-Stop centers:

- Comprehensive centers, where the basic services of those 15 partner programs are available on site. This includes co-location of most staff from these programs.
- Affiliate sites, where most of the basic services of partner programs are available on site. Also referred to as satellite locations, these can be facilities operated by one program but with other partner staff on site. Information on all of the partners programs is available at every location.

There are currently 22 comprehensive One-Stop service centers and 29 affiliate sites across Arizona. All of the physical locations are connected to the AZ Virtual One-Stop, an online database into which prospective employees can upload their résumés. Prospective employers can search résumés from the database as well.

These One-Stop centers are funded through the Workforce Investment Act (WIA). Through WIA, which is actually a national program that provides money to all states, the federal government gives Arizona $68 million a year for workforce development-related activities. Eighty-five percent of that money goes to the local One-Stop centers; 5 percent is dedicated to administration; and 10 percent can be spent on other activities as determined by the Governor's Workforce Council.

The 85 percent dedicated to the One-Stop centers is spent in four areas: 1) dislocated workers looking for a new job; 2) adult workers looking to upgrade their education and/or move to a new job; 3) youths ages 16-21; and 4) rapid response, which includes helping workers find new employment in advance of a company layoff as well as layoff aversion (essentially, paying the company to retain its employees).

**Who uses One-Stop centers?** In the 1990s military budget cuts drove a number of Arizona employers to lay off relatively large numbers of technology workers, who turned to what was then the equivalent of One-Stop centers for employment assistance. After that wave, until recently, people coming to the One-Stop centers for assistance were "largely lower-level kinds of workers."

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[53] Arizona Workforce Connection, 2009 Directory of Arizona One-Stop Sites

[54] The term "dislocated worker" essentially refers to a person who has been laid off from his or her employment.

In a solid economy, traditional users of the One-Stop centers were unskilled or low-skilled workers who needed a skill or certification to make themselves more marketable (e.g. people seeking commercial drivers' licenses to become truckers). Among those "traditional" users of One-Stop services there were very few degreed professionals.

Since the current recession began, though, the One-Stop centers have been working with people at every skill level. One of the workforce development professionals who was interviewed said that the difference between what the One-Stops do, and who they work with, has been "night and day" since the recession began. "At the Phoenix One-Stop centers there has been a huge increase in degreed professionals and technically trained workers seeking employment assistance." The same interviewee referred to this group of people as "unlikely unemployed" – degreed professionals who were laid off in the recession and need to retool their skills for new jobs, "because their old jobs are probably not coming back."

**What are these "non-traditional" One-Stop users looking for?** In a group where many prospective employees have degrees, job seekers must find some differentiator that will elevate their résumé to the top of the pile. For many, that has become a certification (e.g. Lean Six Sigma Green Belt or Black Belt or Project Management Professional). "In this 'new normal' economy it's all about stackable credentials. Employers are looking more at certifications in niche areas than at education." The One-Stop centers pay for those certifications.

Many of the users of One-Stop resources are also looking to brush up on job hunting skills (especially because many of the laid off workers are older and haven't had to job hunt in a long time). So the One-Stop will help with résumé writing and interview skills. One-Stop programs in this area include job readiness training workshops; job search in the 21st century (e.g. how to use the Internet in job search); job club (networking and support group); job club for boomers; and videotaped mock interviews.

**What kinds of programs do the One-Stop centers offer?** In addition to helping people hone their job hunting and interviewing skills, the One-Stop centers are largely dedicated to 1) funding training and development and 2) helping people find jobs. In addition to helping unemployed workers get the skills that will help them find a new job, the One-Stops also provide programs for people who are currently working but want to enhance their skill sets. In both cases, the One-Stop centers don't typically run training programs themselves, but rather provide vouchers for job seekers who choose the provider (from a list of pre-approved entities) and the program under the guidance of a career advisor.

Yet, "training funds are limited and the demand is overwhelming." Because funding is limited, the One-Stops typically pay for certificate programs that are one year or shorter rather than long-term degree programs. For example, One-Stop centers have paid for IT certification programs including PMP, A+, Net+, Cisco certifications, Six Sigma, CCNA, Security+, database, Java, computer support, web development/design, MCSA, MCSE.

In some cases, the One-Stop centers promote training programs for particular skill sets or in particular industries. One center, for example, is currently looking at providing training programs for people to work in the renewable and energy efficiency sectors. The funding for those programs comes from a State Energy Sector Partnership grant, which provides for training people in certified energy management and sustainable building. The One-Stop is targeting dislocated facility managers, engineers, and architects – even those coming from other industries – and helping them retool their skill sets to work in the renewable and energy efficiency sectors. One of the One-Stops is working with the ASU Ira A. Fulton Schools of Engineering to develop a certified energy management certification training program – to "help people elevate their résumé to the top of the pile in the green sector." Again, people will apply for the program, and the One-Stop will pay for their training.

The One-Stop centers also help connect job seekers with employers who have open positions. In addition to the AZ Virtual One-Stop jobs database, the One-Stops also host on-site recruitment events.

**How do the One-Stop centers market their services?** Because the One-Stop centers traditionally served unskilled or low-skilled workers, they have really had to market their services to the "unlikely employed" degreed professionals. One-Stop personnel present at Career Connectors events (that organization is "dedicated to professionals seeking jobs"), and post job opportunities from employers on LinkedIn and in groups like Career Connectors, Southwest Job Network, Tempe Career Network, Wright Management, Career Choice. Sometimes, a One-Stop will host a recruitment event for businesses and prospective employees. In addition, people filing unemployment claim are required to register with an employment service, and the One-Stop centers have a presence at the unemployment office.

**How do the One-Stop centers engage with employers?** Most of the One-Stop centers, certainly the largest ones, have personnel dedicated to liaising with businesses. Typically, their activities fall into one of two categories: 1) job development, where they are helping a business find a single employee; and 2) job fairs, targeted recruitment, targeted résumé searches.

One of the One-Stop leaders who was interviewed said that she meets with company executives "all the time" to discuss what they need and where the holes are in their workforce. But, she said, she is often hard-pressed to help when employers say that they're looking not just for particular certifications but work experience (indeed, see Section 6.3.1).

One-Stop centers do try to help its job seekers get an element of experience – part of the Lean Six Sigma program, for example, was a project within a company. "But it's always hard to get a firm to take on that liability, even if the people are working for free." So, the One-Stop leaders have to think of "creative ways" to meet the experience challenge. One of the One-Stop leaders who was interviewed said that she has not to date seen a willingness among companies to hire people with the right education or skills and then train them to the right experience. "But if they get desperate enough they might."

### 5.3.2 Other Workforce Development and Training Programs

Over the years there have been a number of workforce development and training programs aimed specifically at technology industries in Arizona. One was JACMET, the Joint Alliance of Companies Managing Education for Technology. No longer in operation, JACMET was a collaboration between the state's three public universities and a handful of top technology employers. It was developed in the mid-90s through a federal grant.

The idea behind JACMET was that companies looking for engineering talent have a certain perspective on the educational programs that create the "right-skilled" graduates they needed; that perspective was almost always different than the academics' perspective on educational programs for engineers. The idea behind JACMET was to bring businesses and academics together to share perspectives and ultimately devise programs that would serve everyone's needs. JACMET would develop the kinds of classes that Arizona's employers said they needed; the member companies would then provide those classes. The ultimate goal was to develop master's programs that all three universities would adopt.

The problem, as one of the workforce development professionals who was interviewed articulated it, was that the firms were at the same time (as they always had been) providing education, training, certification, and skill development internally – so they were in effect competing with their own training dollars. When the economy went into recession and companies reined in spending, the Joint Alliance of Companies Managing Education for Technology essentially fell apart. Today, universities and employers report doing that kind of "managing education for technology" collaboration on their own (see Section 5.2.3 and Section 6.5.1) rather than cooperatively in an institutionalized way.

## 5.4 Is Arizona Training Enough S&E Workers?

In Chapter 3 it was argued that while U.S. residents are more mobile than the residents of most other countries, with educated Americans being particularly mobile, there is still a great deal of geographic inertia in people's lives. To the point, Americans who attend college in a state are much more likely to work in that state after they graduate than one would expect in a "flat" world where geography was unimportant. Other things equal, a state that graduates a lot of educated workers is likely to be a state with a relatively educated workforce. When trying to assess whether Arizona technology firms face unusually acute shortages of science and engineering workers, it is useful to ask whether Arizona graduates a large or a small number of scientists and engineers. This kind of analysis was carried out in Section 5.2 using the size of the state's population as a benchmark. A more accurate assessment can be made by comparing the flow of new S&E graduates with the size of the local S&E workforce.

Exhibit 5.8 and Exhibit 5.9 provide a comparison across states of ratios of new S&E graduates to the number of S&E workers. Information is given for 2000 and 2009 and for each of three major S&E groups: computer scientists and mathematicians, architects and engineers, and those involved in the life, physical or social sciences. S&E degrees are aggregated into groups using the procedures described in Exhibit 5.1. Data on employment by major S&E occupation follow the two-digit SOC codes described in Chapter 2.

Conclusions regarding adequacy of local supply are drawn by comparing the ratio of new graduates to workers in a state with the national average. To make the results easier to interpret, the ratios calculated for a state are indexed relative to the nation. An index value below 100 indicates that, when compared with the size of its S&E workforce, the flow of new S&E graduates in a state is below the national average.
States with index values below 100 tend to be net importers of scientists and engineers, and companies located in these states tend to have a relatively difficult time recruiting S&E workers. Opposite conclusions would be drawn for states with an index value over 100.

In the year 2000, Arizona produced relatively few science and engineering graduates when compared with the size of its S&E workforce. This was true for each of the three S&E groups. Index values in that year were 93 for computer scientists and mathematicians, 88 for architects and engineers and 95 for all other scientists. Indexes measuring adequacy of local supply were also below 100 in almost all Western states. For California, Colorado and Washington – Western states with especially large S&E employment – the indexed ratios of new graduates to employed workers were significantly lower than those for Arizona. The values for California in computer-related and engineering fields were each around 75. The relative flow of new architects and engineers in Colorado was on par with the nation, but its relative flow of newly graduated computer scientists and mathematicians was only 68 percent of the national average. For Washington, the indexed ratios for computer scientists and engineers were 55 and 67, respectively. The only Western state with a relatively large flow of S&E graduates was Utah.

### Exhibit 5.8: Index of S&E Degrees Relative to S&E Workforce, 2000 (US = 100)

| State | Computer Science and Mathematics | Architecture and Engineering | Life, Physical and Social Sciences |
|---|---|---|---|
| Alabama | 182 | 188 | 101 |
| Alaska | 50 | 59 | 19 |
| Arizona | 93 | 88 | 95 |
| Arkansas | 226 | 100 | 104 |
| California | 75 | 76 | 101 |
| Colorado | 68 | 104 | 94 |
| Connecticut | 61 | 65 | 100 |
| Delaware | 74 | 123 | 70 |
| D of C | 124 | 99 | 52 |
| Florida | 81 | 88 | 88 |
| Georgia | 84 | 86 | 102 |
| Hawaii | 272 | 118 | 80 |
| Idaho | 94 | 60 | 61 |
| Illinois | 88 | 102 | 109 |
| Indiana | 191 | 160 | 134 |
| Iowa | 136 | 172 | 142 |
| Kansas | 108 | 104 | 153 |
| Kentucky | 132 | 104 | 121 |
| Louisiana | 234 | 120 | 117 |
| Maine | 73 | 76 | 127 |
| Maryland | 96 | 70 | 75 |
| Massachusetts | 86 | 131 | 107 |
| Michigan | 95 | 89 | 83 |
| Minnesota | 64 | 71 | 86 |
| Mississippi | 235 | 127 | 102 |
| Missouri | 121 | 141 | 139 |
| Montana | 257 | 186 | 86 |
| Nebraska | 126 | 105 | 127 |
| Nevada | 50 | 67 | 44 |
| New Hampshire | 154 | 65 | 186 |
| New Jersey | 87 | 85 | 78 |
| New Mexico | 89 | 103 | 54 |
| New York | 185 | 129 | 119 |
| North Carolina | 77 | 103 | 97 |
| North Dakota | 172 | 337 | 114 |
| Ohio | 110 | 111 | 98 |

| | | | |
|---|---|---|---|
| Oklahoma | 135 | 129 | 131 |
| Oregon | 70 | 91 | 95 |
| Pennsylvania | 151 | 144 | 127 |
| Rhode Island | 261 | 203 | 179 |
| South Carolina | 179 | 73 | 142 |
| South Dakota | 170 | 226 | 120 |
| Tennessee | 98 | 106 | 153 |
| Texas | 86 | 77 | 77 |
| Utah | 127 | 158 | 129 |
| Vermont | 162 | 106 | 279 |
| Virginia | 64 | 86 | 111 |
| Washington | 55 | 67 | 66 |
| West Virginia | 178 | 181 | 98 |
| Wisconsin | 109 | 120 | 107 |
| Wyoming | 196 | 152 | 85 |
| United States | 100 | 100 | 100 |

***Explanatory notes:*** *Measures shown are based on the ratio of total degrees awarded in a given S&E field to the number of S&E workers in the field. Ratios are then indexed relative to the nation.*
***Sources:*** *IPEDS and BLS Occupational Employment Statistics*

Numbers for 2009 indicate that flows of new S&E graduates in Arizona have declined further relative to the size of the local workforce. The state's index values for computer scientists and engineers have fallen into the low 80s. Index values for other Western states have changed some in the last ten years but generally remain well below 100. For computer scientists and mathematicians, the index values are 77 in California, 81 in Colorado and 59 in Washington. For architects and engineers, the indexes measuring adequacy of local supply are 81 in California, 91 in Colorado and 51 in Washington.

## Exhibit 5.9: Index of S&E Degrees Relative to S&E Workforce, 2009 (US = 100)

| State | Computer Science and Mathematics | Architecture and Engineering | Life, Physical and Social Sciences |
|---|---|---|---|
| Alabama | 212 | 159 | 155 |
| Alaska | 51 | 43 | 25 |
| Arizona | 83 | 80 | 95 |
| Arkansas | 96 | 98 | 90 |
| California | 77 | 81 | 97 |
| Colorado | 81 | 91 | 91 |
| Connecticut | 66 | 85 | 127 |
| Delaware | 71 | 89 | 54 |
| D of C | 115 | 112 | 68 |
| Florida | 93 | 98 | 114 |
| Georgia | 98 | 104 | 113 |
| Hawaii | 133 | 80 | 75 |
| Idaho | 97 | 83 | 61 |
| Illinois | 135 | 107 | 110 |
| Indiana | 143 | 164 | 112 |
| Iowa | 195 | 151 | 132 |

| | | | |
|---|---|---|---|
| Kansas | 79 | 92 | 103 |
| Kentucky | 121 | 101 | 131 |
| Louisiana | 179 | 99 | 120 |
| Maine | 56 | 77 | 134 |
| Maryland | 110 | 70 | 72 |
| Massachusetts | 86 | 115 | 93 |
| Michigan | 143 | 112 | 115 |
| Minnesota | 88 | 75 | 93 |
| Mississippi | 172 | 109 | 127 |
| Missouri | 112 | 120 | 138 |
| Montana | 136 | 148 | 59 |
| Nebraska | 129 | 131 | 118 |
| Nevada | 88 | 63 | 66 |
| New Hampshire | 71 | 78 | 174 |
| New Jersey | 55 | 90 | 79 |
| New Mexico | 136 | 72 | 44 |
| New York | 146 | 158 | 113 |
| North Carolina | 90 | 115 | 93 |
| North Dakota | 159 | 257 | 94 |
| Ohio | 96 | 126 | 111 |
| Oklahoma | 115 | 134 | 135 |
| Oregon | 83 | 73 | 75 |
| Pennsylvania | 165 | 136 | 108 |
| Rhode Island | 213 | 193 | 203 |
| South Carolina | 120 | 58 | 143 |
| South Dakota | 172 | 210 | 99 |
| Tennessee | 110 | 100 | 145 |
| Texas | 70 | 75 | 85 |
| Utah | 141 | 114 | 124 |
| Vermont | 201 | 87 | 191 |
| Virginia | 65 | 95 | 120 |
| Washington | 59 | 51 | 60 |
| West Virginia | 174 | 138 | 127 |
| Wisconsin | 116 | 98 | 106 |
| Wyoming | 141 | 79 | 48 |
| United States | 100 | 100 | 100 |

***Explanatory notes:*** *Measures shown are based on the ratio of total degrees awarded in a given S&E field to the number of S&E workers in the field. Ratios are then indexed relative to the nation.*
***Sources:*** *IPEDS and BLS Occupational Employment Statistics*

The results in Exhibit 5.8 and Exhibit 5.9 are consistent with a description of the Arizona job market in which local firms have a relatively hard time finding qualified science and engineering workers and must rely more than the average U.S. employer on S&E workers who have migrated to the state. However, given the success states such as California, Colorado and Washington have had in creating jobs for and recruiting S&E workers, it is clearly not necessary for a state to rely exclusively or even primarily on local colleges and universities to meet its S&E manpower needs. Of course, operating without a large local supply of new graduates is easier to accomplish if migrant scientists and engineers find your state to be an attractive place to work and live.

# 6 Survey of Arizona Technology Firms

## 6.1 Overview

At the onset of this study, the report authors set out to determine the supply of technology talent in Arizona, and Arizona employers' demands for technology talent. Set side-by-side, does the demand of Arizona employers for computer scientists, engineers, and scientists outweigh Arizona's supply of those technology employees?

The answer to that question is no. But there are a number of nuances. First, labor in the U.S. is mobile (see *Chapter 3*). Graduates of Arizona universities go to work for employers in other states, and graduates of universities in other states come to work for employers in Arizona. Similarly, experienced employees at firms in other states come to work for employers in Arizona – and vice versa. So to set Arizona firms' demand against the supply of technology workers from other Arizona firms and Arizona universities is too restrictive. The market is more flexible than that.

Indeed, while most of the technology employers who were interviewed reported that they would prefer to source local talent rather than relocate candidates from other places, many firms said that getting candidates from other places was not a significant source of stress. Survey respondents indicated that 41 percent of the computer scientists, 39 percent of the engineers, and 46 percent of the scientists they had hired had come from out of state. For other companies, though, the local supply was much more important, and a number of firms reported finding it difficult to get candidates to move to Arizona (though not for the reasons one might initially expect, see Section 6.7.3).

In the electronic survey, if a respondent said that less than half of their recent hires had come from out of state, they were asked to give the reasons for that. Of the 106 respondents who were asked this question about their hiring of computer scientists, 68 checked a response stating that they could find enough qualified computer scientists to hire from the local area. Only 21 of these respondents checked a response stating that they could not get external candidates to move to Arizona. There were 79 respondents who said that less than half of their newly hired engineers moved to Arizona from out of state. When asked why, 52 indicated that there was sufficient local availability. There were 16 respondents who said that it was difficult to get engineers from out of state to move to Arizona. Of the 17 respondents who said that less than half of their recent scientist hires had come from out of state, 3 said they could not get scientists to move here.

The second nuance to the supply-versus-demand setup is that firms are not just looking for *any* computer scientists or *any* engineers or *any* scientists. Within each occupational category, firms have criteria they use to define a "qualified" candidate. Those criteria include, not least of all, levels of experience and education (as well as many other factors, see Section 6.3).

Indeed, one of the goals of the survey and interview effort was to learn about the recruiting practices, preferences, and experiences of local technology companies. Does the company hire fresh graduates, or does it prefer people with substantial work experience? The survey indicates (and interviews affirmed) a strong preference for computer scientists, engineers, and scientists with work experience. Survey respondents reported that only 23 percent of recent hires of computer scientists and 29 percent of recently hired engineers were either fresh graduates or had less than two years of work experience. Forty-four percent of the computer scientists hired and 33 percent of the engineers had more than five years of work experience.

So to put *all* computer scientists, engineers, and scientists in Arizona into a pool together and call them the supply of technology talent misses firms' much more specific demand, including for different levels of experience. Even to pool all recently graduated technology workers together and, separately, all experienced technology workers together misses firms' specific demand, including for certain key skill sets.

The third nuance that makes answering the "Set side-by-side, does Arizona demand equal Arizona supply?" question more difficult is that many firms are constrained by an inability to hire foreign nationals, who make up a sizable percentage of educated technology workers and an increasingly large percentage of graduates of master's-level and Ph.D.-level programs in science, technology, engineering, and math (STEM).

When the report does set Arizona demand side-by-side with Arizona supply, only one interviewee described true pure quantity constraints (see Section 6.7.1). For all of the other firms reporting difficulty attracting "qualified" technology workers there was some more nuanced explanation of their supply/demand gap. Not enough technology workers had the right skill sets (6.6.3), or not enough had three or five or eight or more years of work experience (6.6.1), or not enough had requisite soft skills (6.6.5), or not enough lived in Arizona (though interviewees suggested a relatively high degree of labor mobility).

Nor did interviewees even suggest that Arizona's universities are simply not graduating enough engineers, computer scientists, or scientists. They might not be graduating enough "A" students in those fields (6.6.2). They might not be graduating enough U.S. citizens in those fields (6.7.4). They might not be graduating enough students with the right specialized skills or hands-on experience (6.6.4).

Overall, for both computer scientists and engineers, there was little in the survey responses to suggest that Arizona technology companies are failing to hire Arizona graduates because of a perceived lack of quality or skills. In the survey, if a respondent indicated that less than half of recent hires had a degree from an Arizona institution, there was a follow up question on the reasons for that. There were several pre-defined responses that could be checked, including a statement that Arizona graduates generally lacked the skills needed to perform the job and a statement indicating that the company had established recruiting relationships with schools located out of state.

There were 94 respondents who answered this question for computer scientists. Sixteen (17 percent) of these respondents stated that Arizona graduates lacked the necessary job skills. Seventeen indicated that they did not generally hire new graduates from Arizona institutions because they had recruiting relationships with schools outside of the state. There were 75 respondents who said that less than half of the newly graduated engineers they had hired came from Arizona schools. When asked why, the reasons given were similar to those given for computer scientists. Seventeen of the 75 (23 percent) said that Arizona graduates did not have the skills required. A similar number explained that they had developed recruiting relationships with schools outside of the state. Nineteen respondents answered this question for scientists. Of those, 6 said that Arizona graduates did not have the specific skills required.

But to say that the answer to the demand/supply question is nuanced is not to say that Arizona employers find it *easy* to attract qualified computer scientists, scientists, and engineers. In the final part of the survey, respondents were asked generally about how difficult it has been to attract qualified science and engineering workers to fill positions in their companies. There were three possible responses. Attracting qualified technology workers was: very difficult, somewhat difficult, or not difficult at all.

The responses for computer scientists were distributed evenly around the "somewhat difficult" response. Twenty-three and a half percent said that it was very difficult; 53 percent said that it was somewhat difficult; and 23.5 percent said that it was not difficult at all. Firm conclusions either way cannot be drawn from this distribution of responses, though it seems to be easier to recruit engineers than computer scientists. Fifty-two percent reported it was "somewhat difficult" to attract qualified engineers; 15 percent reported attracting qualified engineers was "very difficult" and 33 percent said "not at all difficult." Among employers of scientists, 11 percent said attracting qualified workers was "very difficult" and 87 percent said it was "somewhat difficult."

**The sections that follow will explore the nuances in supply/demand constraints as they were reported by the interviewees. Throughout these sections the report incorporates survey results with information gleaned from the in-depth interviews. The report looks specifically at:**

**What does a "qualified" candidate look like?** Section 6.3 considers the job requirements of Arizona's technology employers. What are they looking for in their technology workers? What criteria do they use to define a "qualified" candidate? Here, survey data includes a breakdown of technology employees by specialty of occupation, by level of educational attainment, and work experience of recent hires. In this section and others, tabulations are made by the employment size class of the reporting firms. The report also covers the details associated with qualifications reported by interviewees, including:

- At least 2-3 years of work experience
- Education
- Specific skill sets
- Hands-on experience
- Soft skills
- Foundational skills
- Cultural fit

**Where are those qualified candidates coming from?** Section 6.4 considers where those "qualified" job candidates that Arizona's technology employers are looking for come from. Survey data includes education of recent grads hired (in-state or out-of-state, and why) and recent hires who moved from out of state (and why). The section will detail the reported sources of qualified candidates, including:

- Other firms in Arizona
- Other firms outside Arizona
- Universities
- 2-year schools
- Internship programs
- H-1B visa programs (for foreign nationals)

- Workforce development and training programs
- Contract (temporary) agencies
- The military

**What is the process by which firms source qualified talent?** Section 6.5 discusses the ways that employers find qualified candidates as they're defined in Section 6.3 from the sources described in Section 6.4. The sourcing processes detailed in this section include:

- University engagement
- Recruiting agencies (headhunters)
- Job boards
- Referrals
- Growing talent from within (build versus buy)

**Do firms have difficulty attracting qualified technology workers? Where does that difficulty lie?** Section 6.6 tackles first the question of whether employers have had difficulty attracting qualified candidates as they're defined in Section 6.3. Then the report asks, if attracting qualified talent has been difficult, is that difficulty particularly acute for certain qualifications? Or certain sources? Survey data includes responses about difficulty attracting "qualified" technology workers.

**What are the root causes of that reported difficulty?** Section 6.7 looks at the root causes of firms' difficulty in attracting "qualified" talent in Arizona. What's behind the difficulty in attracting qualified technology talent? The report considers a number of potential root causes, including:

- Quantity constraints (simply not enough tech workers)
- People don't want to move to Arizona
- Lack of industry concentration in Arizona
- The H-1B issue (employers say, "the candidates might be 'qualified' but we can't hire them")

**What are potential solutions?** The interviewer asked interviewees two solutions-oriented questions:

1) If you had a magic wand and could do anything to resolve your difficulty in attracting qualified technology talent, what would you do?
2) If you were sitting at the table with Arizona's top policymakers and the heads of STEM departments at the state's educational institutions, what would you ask them to do to make it easier for you to attract qualified technology talent?

The responses that the report explores in Section 6.8 include:

- What might companies do to address the talent sourcing difficulty? From realigning the recent graduate/experienced worker ratio to changing job requirements.
- What might policymakers do to address the talent sourcing difficulty? From developing "core" industries to countering misperceptions about Arizona's schools.
- What might universities do to address the talent sourcing difficulty? From tailoring curricula to business needs to offer more hands-on experience.

## 6.2 The Survey and Interview Processes

A primary objective of this project was to survey local technology firms (first through an electronic survey and then through follow-up interviews) to document the hiring practices and recruiting experiences of companies who have hired computer scientists, engineers, and scientists to work at their facilities in Arizona. Does the company hire fresh graduates, or does it prefer people with substantial work experience? Among the new graduates hired, does the company recruit primarily from Arizona programs and universities, or does it have established relationships with out-of-state institutions? What has been the experience of the company when it has hired graduates of Arizona institutions? If the company tends not to hire Arizona graduates, why is that? If a company does not recruit significantly from out of state, why is that?

When filling its positions for more experienced scientists and engineers, how reliant is the company on out-of-state recruiting? Has the company found it difficult to get scientists and engineers to move to Arizona? What has been the company's overall experience when recruiting scientists and engineers to work in Arizona? Has the company found it difficult to attract technology workers, or has it been relatively easy to find qualified scientists and engineers?

The complete survey instrument is reproduced in Appendix A . Exhibit 6.1 provides an abbreviated summary of the survey. Follow-up interviews were designed to dig deeper into the firms' responses to the survey questions, and to explore the firms' ideas about potential solutions to the challenges and opportunities they face.

### Exhibit 6.1: Abbreviated Summary of Questions in Company Survey[55]

| |
|---|
| **Number and type of technology workers employed**<br>• How many *Computer Scientists* do you employ? How are they divided between the following categories: programmers, software engineers, network and systems administrators, support specialists, others?<br>• How many *Engineers* do you employ? How are they divided between the following categories: electrical and electronics engineers, industrial engineers, mechanical engineers, engineering drafters and technicians, others?<br>• How many *Scientists* do you employ? How are they divided between the following categories: biochemists and biophysicists, microbiologists, chemists, chemical technicians, physicians, others? |
| ***The following questions were asked for each of the three broad groups of technology workers (computer scientists, engineers, and scientists)*** |
| **Educational attainment**<br>• What percent of your technology workers have as their highest degree attained no college degree? A 2-year college degree? A bachelor's degree? A master's or Ph.D.? |
| **Work experience of recent hires**<br>• What percent of the technology workers that you've recently hired had less than 2 years of work experience when you hired them? Had between 2 and 5 years of work experience? Had more than 5 years of work experience? |
| **Hires of new graduates**<br>• Among the recent graduates you have hired, i.e., those who just graduated or had less than 2 years of work experience, what percent had graduated from an Arizona institution? |

[55] See Appendix A for the complete survey

| |
|---|
| o If less than half of the recent grads you have hired were graduates of an Arizona institution, why is that? Check all that apply.<br>▪ Graduates from Arizona institutions do not have the specific skills we need<br>▪ Few graduates from Arizona institutions apply, or they accept other offers<br>▪ We have established recruiting relationships with schools outside the state<br>▪ Other reasons (please describe) |
| **Out-of-state recruiting**<br>• What percent of the technology workers that you've recently hired were living outside of Arizona when you hired them?<br>o If less than half of the technology workers you've recently hired came from outside Arizona, why is that? Check all that apply.<br>▪ There is sufficient local availability<br>▪ We cannot get these workers to move to Arizona<br>▪ Other reasons (please describe) |
| **General difficulty attracting technology workers**<br>• How difficult is it for you to attract qualified technology workers? Check the one that best applies.<br>▪ Not difficult at all<br>▪ Somewhat difficult<br>▪ Very difficult<br>o Is that difficulty particularly acute for certain skill sets, experience, or education? Please explain. |

### 6.2.1 The Survey Process

It was not the intention to count every single computer scientist, engineer, and scientist working in Arizona. That task is already effectively carried out by the Bureau of Labor Statistics in its annual Occupational Employment Statistics Survey. The information the report authors were interested in could be obtained from a sample of Arizona employers. To try to be as inclusive as possible, however, a considerable effort was made to solicit information from a large number of companies – many more than was necessary to obtain statistically meaningful results.

The report authors were primarily interested in the hiring experiences of technology companies, as defined in Exhibit 4.7. The important public policy issues concern the adequacy of technology workers for firms that *produce* new technology, not firms that *use* new technology. Every sector of the economy now makes use of information technology, for example, and employs computer support specialists, programmers and network administrators. Banks are among the most IT-intensive firms in the economy. Yet most companies that use IT, including banks, are not involved in computer science research or in the development of new IT hardware or software.

To learn about the hiring experiences of companies that employ engineers, the survey focused on companies whose business it is, for example, to develop new medical devices or new rockets for missile defense systems, as opposed to practitioners of engineering such as construction firms. When inquiring about possible shortages of scientists, the survey targeted companies involved in medical research and companies that employ chemists to create new industrial products, for example, rather than organizations that deliver health care services.

#### 6.2.1.1 Who Received the Survey?

To establish the list of technology employers to survey the report authors started with four sources of Arizona employer data: 1) the National Establishment Time-Series (NETS) database; 2) the employment database of the Maricopa Association of Governments (MAG); 3) the Arizona Technology Council (AzTC) membership list; and 4) the Arizona Bioindustry Association (AZBio) membership list. From those sources the list was refined to include only:

- Firms classified by one of the North American Industry Classification System (NAICS) codes that were defined as relating to technology employers (see Exhibit 4.7 for a list of these NAICS codes) and having at least 100 employees
- Arizona Technology Council "technology industry" members with four or more employees; excluding AzTC members that are government entities, non-profits, or "associates" (e.g. banks, law firms, accounting practices, consulting firms, utility companies)
- Arizona Bioindustry Association (AZBio) members

Once a list of companies to which the survey would be sent (a total of 281) was defined, an appropriate contact person at each firm was determined. The report authors are indebted to the Arizona Technology Council and AZBio for their help identifying the appropriate contact people at their member firms. For the remaining companies on the list who were not members of those organizations, the authors sourced contact information from company websites, Hoover's, and NetProspex.

Because the aim was always to get an "on-the-ground" perspective of employers' experiences recruiting and hiring scientists and engineers in Arizona, the perspective of managers directly involved with hiring and managing technology employees was sought. To that end, the list was split into two categories: those companies with less than 100 employees and those with 100 employees or more. For those with fewer than 100 employees the survey was sent directly to the contact person on file (often a senior-level executive).

For those companies with 100 or more employees the contact person on file (generally a higher-level executive) was contacted with a request for a list of names and contact information of department or facility-level managers who oversee technology workers at the company's facilities in Arizona. Once the names of those managers were received, the report authors reached out to them directly with the survey. For that reason, multiple survey responses from some companies – mostly the larger employers – were received.

The survey was web-based, provided on the SurveyMonkey platform. Respondents were directed to a unique URL to complete the survey. From the date the survey was opened (December 6, 2010) to the date it was closed, July 8, 2011), 172 complete responses from 141 employers were received.

Following up with the 281 companies on the list to maximize the response rate was a monumental endeavor; the report authors are extremely grateful for the dedicated assistance of the Arizona Technology Council workforce study committee members who worked tirelessly to help maximize the survey and interview response. All told, nearly 20 rounds of e-mails were sent and more than 5 rounds of telephone calls were made to companies to ask for their participation in the survey and interview process.

The authors of this report send a heartfelt thank you to Hugh Barnaby (ASU), Travis Beeman (KPMG), Kathy Collins (Boeing), Ed Escobedo (Apollo Group), Janice Grandy (The Foundation for Public Education), Todd Hardy (ASU), James Powers (iLinc), Susan Shultz (SSA Executive Search International Ltd.), Justin Williams (Arizona Technology Council), Deborah Zack (Arizona Technology Council), and Steve Zylstra (Arizona Technology Council) for their invaluable assistance.

#### 6.2.1.2 Background Information on Survey Respondents

One hundred seventy-two individuals from a total of 141 Arizona employers responded completely to the survey. Exhibit 6.2 shows the participating companies. In some cases, there were several separate facilities or establishments within a company that completed the survey. Exhibit 6.3 provides background information from the survey on the number of S&E workers reported and the size distribution of the surveyed establishments as measured by the number of S&E workers they reported employing.

The survey was highly successful in soliciting information from employers of computer scientists and engineers. A total of 134 respondents reported that they employ computer scientists. Together these respondents employ 6,093 computer scientists, which is approximately 10 percent of total Arizona employment in computer-related occupations. There were 110 respondents who reported employing engineers. The number of engineers reported by these respondents was 14,426, which is approximately 30 percent of total Arizona employment of engineers. Survey coverage of engineers was higher than the coverage of computer scientists because of the wide dispersion of computer scientists across the economy. The survey focused on technology companies. Only 26 respondents completing the survey indicated that they employ life and physical scientists. The total number of scientists reported by these respondents was 740. The proportions of computer scientists, engineers and physical scientists spanned by the survey are well “less than half” when compared with government estimates of their respective total labor markets. But the survey spanned a very large proportion of the employment base of those businesses engaged in innovative and foundational technology pursuits – arguably the core of the technology labor market which was the primary focus of our study.

The size distribution of surveyed respondents was heavily skewed toward small employers. Out of a total of 172 individuals completing the survey, 95 employed 24 or fewer S&E workers. Completed surveys from almost all of the very large technology companies in Arizona were successfully obtained. There were 5 surveyed respondents who employ 1,000 or more S&E workers and 8 respondents who employ between 250 and 999 S&E workers. Together these 13 respondents account for 71 percent of the 21,259 S&E workers identified in the survey.

Summaries of responses are provided in the exhibits throughout this chapter. For questions in which the respondent is asked to check a numerical range, midpoints of ranges are used to summarize responses. The results are then weighted by the number of S&E workers employed in order to recognize the relative importance of larger establishments.[56]

[56] To take an example, when asked about the work experience of the S&E workers a company has recently hired, the respondent is presented with three categories of work experience: less than 2 years of work experience, 2 to 5 years of work experience, and more than 5 years of work experience. For each of these three categories, the surveyed party is asked what percent of their hires were people with that category of work experience, with the possible responses being given in quartiles, e.g., 0-24%, 25-49%, etc. Suppose that an establishment reports that 0-24% of their recent hires had less than 2 years of work experience, that 25-49% had 2-5 years of work experience, and that 25-49% had more than 5 years of work experience.

## Exhibit 6.2: List of Companies That Completed the Survey

| | |
|---|---|
| AbilityCRM | Jobing |
| Able Information Technologies, Inc. | Kinetic Muscles, Inc. |
| ADI Computer Solutions | KinetX, Inc |
| Advatech Pacific | Kutta Technologies, Inc. |
| AGM Container Controls, Inc. | Level 3 Communications |
| Airband Communications | Lumension Security |
| Airtronics | Marvell Semiconductor |
| Arizona Instrument LLC | Mastek-InnerStep, Inc. |
| Ascent Aviation Services Corp. | Medipacs Inc. |
| AT&T | Merchants Information Solutions, Inc. |
| ATOMdesign | MesaBio |
| Audio Eye, Inc. | MicroBlend, Inc. |
| Avnet | Microchip Technology Inc |
| Axosoft, LLC | Microsoft |
| Axway | MSS Technologies, Inc |
| bioVidria, Inc. | Multitest |
| Breault Research Organization | Namescape Corporatiion |
| Cactus Custom Analog Design | Net Fusion Services |
| Celgene Corporation | Northrop Grumman |
| CH2M HILL | NXP Semiconductors |
| CIBER, Inc | ON Semiconductor |
| Cord Blood Registry | OneNeck IT Services |
| Cox Communications | Orbital Sciences Corporation |
| Custom Storage | OSAM Document Solutions, Inc. |
| CyberTrails, LLC | Pacific Scientific Energetic Materials Co. |
| Darling Environmental & Surveying, Ltd. | PADT, Inc. |
| Data Doctors | Paragon Space Development Corporation |
| DPR Construction | Phoenix NAP LLC |
| Edmund Optics | Polymap Wireless |
| End 2 End Technologies | Prescio Consulting, LLC |
| Ensynch, Inc. | ProVision Communications |
| Enterprise Technology Services | Raytheon Missile Systems |
| EOS Technologies, Inc. | Regenesis Biomedical |
| EV Group | Results Direct |
| Face to Face Live, Inc. | Rincon Research Corporation |
| Fennemore Craig, PC | Rowpar Pharmaceuticals |
| FireDrum Internet Marketing | Sage |
| Flinn | Securplane |
| Flip Chip International | simpleview, Inc |
| Flodraulic Group Inc | Sindel Technologies, LLC |

For the summaries shown in the exhibits, 12% as a response for the first category and 37% as responses for the second and third categories would be used. The results would then be scaled to add up to 100%. So this establishment's responses would be summarized as follows: 14% (or 12/86) of their recent hires had less than 2 years of work experience, 43% (or 37/86) had 2 to 5 years of work experience, and 43% had more than 5 years of work experience.

| | |
|---|---|
| Forensics Consulting Solutions | Solid Concepts, Inc. |
| Freescale Semiconductor | SOLON Corporation |
| Garmin International | Solugenix Corporation |
| Gate6, Inc. | Sonora Quest Laboratories |
| GE Healthcare Ultrasound Probes | Speedie & Associates |
| General Dynamics C4 Systems | St. Jude Medical |
| General Plasma Inc. | Steward Observatory, University of Arizona |
| Global Patent Solutions, LLC | SUMCO |
| Global Solar Energy | Syntellect |
| Goodrich | Telesphere |
| Hard Dollar Corp. | Teris - Phoenix |
| HDR Architecture, Inc | TGen |
| Honeywell Aerospace | The Boeing Company |
| Hypercom | The CORE Institute |
| iCrossing | The Janzen Wahl Group, LLC |
| iLinc | The Stratford Group, Inc. |
| ImageTag, Inc. | The University of Arizona - Office of University Research Parks |
| Infrared Laboratories | Ticer Technologies |
| Infusionsoft | Trans-West Network Solution |
| Insight Enterprises | Tucson Embedded Systems, Inc. |
| Institute for Scientific and Space Research, Inc. | Ulthera, Inc. |
| Integrum Technologies | Universal Avionics |
| Intel Corporation | University of Arizona, Dept of Ag and Biosystems Engineering |
| Interface | Vante Medical Technologies |
| Intuit | Ventana Medical |
| Isos Technology | Virtuon |
| IT Partners | VisionMOS |
| iT1 | Xlcon |
| Jabil Circuit, Inc. | XO Communications |
| J-Curve Technologies | Yulex Corporation |
| JDA Software | |

### Exhibit 6.3: Background Statistics on Establishments Participating in the Survey

| | |
|---|---|
| **Number of establishments reporting employment by category** | |
| Computer scientists | 134 |
| Engineers | 110 |
| Scientists | 26 |
| **Total number of employees reported by category** | |
| Computer scientists | 6,093 |
| Engineers | 14,426 |
| Scientists | 740 |
| **Total S&E workers** | **21,259** |
| **Size distribution of establishments based on total S&E workers reported** (number of establishments in size class) | |
| 1000 or more | 5 |
| 250-999 | 8 |
| 100-249 | 23 |
| 50-99 | 18 |
| 25-49 | 23 |
| 10-24 | 49 |
| 1-9 | 46 |

### Exhibit 6.4: Statistics on Computer Scientists

| | |
|---|---|
| **Total reported employment of computer scientists** | **6,093** |
| **Number of establishments by employment size class** | |
| 200 or more | 6 |
| 100-199 | 9 |
| 50-99 | 14 |
| 25-49 | 14 |
| 10-24 | 38 |
| 1-9 | 53 |
| **Percent of total employment by size class** | |
| Large establishments (100 or more) | 63.7% |
| Medium-sized establishments (25-99) | 23.8 |
| Small establishments (1-24) | 12.5 |

### Exhibit 6.5: Statistics on Engineers

| **Total reported employment of engineers** | **14,426** |
|---|---|
| **Number of establishments by employment size class** | |
| 1000 and above | 5 |
| 250-999 | 4 |
| 100-249 | 15 |
| 50-99 | 8 |
| 25-49 | 12 |
| 10-24 | 24 |
| 1-9 | 42 |
| **Percent of total employment by size class** | |
| Very large establishments (1000 or more) | 57.7% |
| Large establishments (100-999) | 31.3 |
| Medium-sized establishments (25-99) | 7.1 |
| Small establishments (1-24) | 3.9 |

### Exhibit 6.6: Statistics on Scientists[57]

| **Total reported employment of scientists** | **740** |
|---|---|
| **Number of responding establishments by employment size class** | |
| 50 or more | 4 |
| 10-49 | 4 |
| 1-9 | 18 |

## 6.2.2 The Interview Process

The survey instrument (which is reproduced in full in Appendix A ) was designed to maximize complete responses while still generating useful information (a much longer instrument that was heartily rejected by the small group of pilot test respondents was initially used). To get a deeper look into firms' experiences with technology employees in Arizona, in-depth interviews with a subset of survey respondents were conducted.

### 6.2.2.1 Who Was Solicited for an Interview?

Interview requests were sent to a total of 56 firms that had responded to the survey and met certain criteria. The criteria for selecting the subset of firms that were solicited for interviews were:

- All companies with more than 100 employees who responded to the online survey and have a technology-related NAICS code (see Exhibit 4.7)
- All companies with 100 employees or fewer and a technology-related NAICS code who responded to survey and reported that hiring is "very difficult"

[57] Only 26 surveyed establishments reported employing scientists. With so few respondents, the report will focus on results across all establishments and not try to draw any conclusions about differences in results by size of employer.

Interviews were conducted with 47 individuals at 33 of the 56 firms that were solicited for interviews. Again, all of these firms were survey respondents listed in Exhibit 6.2. To preserve the sometimes sensitive nature of the discussions, the names of the interviewees are not listed. Throughout the sections that follow the interviewees are identified by industry and, in Exhibit 6.25, by NAICS code.

In some cases, interviewees were the same individuals who completed the survey. In other cases, where the survey respondent was a hiring manager, an executive was interviewed (and vice versa: when the respondent was an executive, a hiring manager was interviewed). Titles of interviewees include:

- CEO
- Chief Engineer
- Chief Information Officer
- Chief Technology Officer
- Global Human Resource Manager
- HR Director
- IT Director
- IT Manager
- Partner
- President
- Recruiting Manager
- Senior Director of R&D
- Senior Human Resource Generalist
- Talent Acquisition Manager
- Test Engineering Manager
- Vice President of Research and Development
- VP Engineering
- VP Human Resources

## 6.3 What Does a "Qualified" Candidate Look Like?

This section considers what Arizona's technology employers report as job requirements. What are they looking for in their technology workers? What criteria do they use to define a "qualified" candidate? Here, survey data includes employment breakdown by job category, employment breakdown by level of educational attainment, and work experience of recent hires.

### Exhibit 6.7: Employment by Job Category

| **Computer scientist employment breakdown by job category (Percent of total)** | |
|---|---|
| Programmers | 13.6% |
| Software engineers | 48.8 |
| Network and systems administrators | 12.3 |
| Support specialists | 15.3 |
| Other | 10.0 |
| **Engineer employment breakdown by job category (Percent of total)** | |
| Electrical and electronics engineers | 42.0% |
| Industrial engineers | 1.2 |
| Mechanical engineers | 22.7 |

| | |
|---|---|
| Engineering drafters and technicians | 4.6 |
| Other | 29.6 |
| **Scientist employment breakdown by job category (Percent of total)** | |
| Biochemists and biophysicists | 1.5% |
| Microbiologists | 1.9 |
| Chemists | 50.9 |
| Chemical technicians | 1.3 |
| Physicists | 17.0 |
| Other | 27.3 |

### 6.3.1 Work Experience

Not surprisingly, the survey portrays a job market for computer scientists in which employees work for many different employers over their working lives and where the typical person hired is someone with some work experience rather than a fresh college graduate. The survey indicates that only 23 percent of recent hires of computer scientists were individuals with less than two years of work experience. Thirty-three percent of those recently hired had 3 to 5 years of work experience, and 44 percent had more than five years. There was very little difference across establishments of different sizes in the experience profile of newly hired computer scientists.

### Exhibit 6.8: Work Experience of Recent Computer Scientist Hires (Employment Weighted)

| **All establishments** | **Percent of total** |
|---|---|
| New grads | 22.7% |
| 2-5 yrs work experience | 33.3 |
| More than 5 yrs work experience | 44.0 |
| **Large establishments** | |
| New grads | 22.2 |
| 2-5 yrs work experience | 32.0 |
| More than 5 yrs work experience | 45.8 |
| **Medium-sized establishments** | |
| New grads | 24.9 |
| 2-5 yrs work experience | 35.7 |
| More than 5 yrs work experience | 39.4 |
| **Small establishments** | |
| New grads | 20.6 |
| 2-5 yrs work experience | 35.9 |
| More than 5 yrs work experience | 43.5 |

As is true for other technology workers, the market for engineers is characterized by a high degree of job turnover and movement of workers between different employers. This is evident in the survey from the fact that of all recently hired engineers, 38 percent had between 3 and 5 years of work experience when they were hired, and 33 percent had more than 5 years of experience. Only 29 percent were hired fresh out of college or with less than two years of experience.

The percentage of new engineering graduates hired is somewhat higher than the corresponding 23 percent figure found for computer scientists. The survey also indicates that small establishments are more likely to recruit engineers with work experience than are large establishments. Of the engineers hired by small and medium-sized establishments, 46 percent and 41 percent, respectively, had more than 5 years of work experience. Among the very large establishments, only 29 percent of recent hires had more than 5 years of experience.

### Exhibit 6.9: Work Experience of Recent Engineer Hires (Employment Weighted)

| **All establishments** | **Percent of total** |
|---|---:|
| New grads | 28.9% |
| 2-5 yrs work experience | 37.7 |
| More than 5 yrs work experience | 33.4 |
| **Very large establishments** | |
| New grads | 25.0 |
| 2-5 yrs work experience | 46.5 |
| More than 5 yrs work experience | 28.5 |
| **Large establishments** | |
| New grads | 37.7 |
| 2-5 yrs work experience | 23.1 |
| More than 5 yrs work experience | 39.2 |
| **Medium-sized establishments** | |
| New grads | 24.2 |
| 2-5 yrs work experience | 34.7 |
| More than 5 yrs work experience | 41.0 |
| **Small establishments** | |
| New grads | 23.4 |
| 2-5 yrs work experience | 31.0 |
| More than 5 yrs work experience | 45.5 |

As with other technology workers, the great majority of recently hired scientists already had significant work experience. Only 19 percent were fresh out of school or had less than 2 years of work experience.

### Exhibit 6.10: Work Experience of Recent Scientist Hires (Employment Weighted)

| **All establishments** | **Percent of total** |
|---|---:|
| New grads | 19.3% |
| 2-5 yrs work experience | 22.2 |
| More than 5 yrs work experience | 58.5 |

All of the interviewees reported that at least some positions require the candidate to have 2-3 years or more of relevant work experience. Why? The two most common reasons interviewees cited were:

1) Candidates with relevant experience are typically productive more quickly (they "hit the ground running"). One interviewee who said that experience is paramount described these candidates as "plug-n-play."

2) Candidates with relevant experience are more likely to possess the specific (niche) skills that companies require for some positions (see Section 6.3.3).

In most cases, even the most experienced new hires require some on-the-job training – at least for higher-level positions. Nevertheless, most interviewees said, less training time is better than more. The need for short time-to-productivity is particularly acute among smaller firms, who typically have fewer resources for training new hires.

Among those smaller firms looking exclusively for candidates with experience, a number of them look for candidates with diverse experience and demonstrated flexibility. Often, that is because the smaller employers require "all hands on deck" (everyone contributing to every project) and do a broader range of work than larger companies with divisions that focus exclusively on very specific products or services.

But even some of the larger firms focus primarily on candidates with work experience. One aerospace and defense interviewee said that while the company does hire recent graduates they also look for experienced workers who have a résumé that shows relevant experience with other employers (like NASA, he said).

For lower-level technology workers (technicians), a few interviewees reported preferring experience in lieu of education. "We don't care about the degree, but rather about hands-on experience – demonstrated technical expertise," one interviewee said. She added that her firm invested a lot of time in the technical interview process with specific questions to assess candidates' technical abilities. (See also Section 6.3.5.2 for a discussion of the interview process.)

### 6.3.2 Education

The survey identified a total of 6,093 employees as being in computer-related occupations. The largest numbers (49 percent) were software engineers. Only 13 percent of those in computer-related occupations had less than a 4-year college education. Roughly 67 percent had a bachelor's degree, and 20 percent had either a master's or a Ph.D. Computer scientists with an advanced degree were a little more likely to be employed in large establishments than in small ones. Establishments employing at least 100 computer scientists accounted for 64 percent of all workers in computer-related occupations but 70 percent of those with either a master's or a Ph.D.

## Exhibit 6.11: Education of Computer Scientists

| **Employment breakdown by level of educational attainment** | **Percent of total** |
|---|---|
| No college | 5.9% |
| 2-year college degree | 7.4 |
| Bachelor's degree | 67.2 |
| Master's or Ph.D. | 19.5 |
| **Computer scientists with a master's or Ph.D. by size class** | **Percent of total** |
| Large establishments | 70.2% |
| Medium-sized establishments | 21.1 |
| Small establishments | 8.7 |

The engineers reported in the survey were also highly educated. Only 10 percent had less than a 4-year college education. The survey indicates that 29 percent of the engineers employed by Arizona technology companies have either a master's degree or a Ph.D. This is a higher number than the 20 percent figure reported for computer scientists. As was the case with computer scientists, large employers are somewhat more likely to employ engineers with advanced degrees than are small employers. The survey indicates that establishments employing at least 1,000 engineers account for 58 percent of all engineers but 66 percent of engineers with a master's degree or Ph.D.

### Exhibit 6.12: Education of Engineers

| **Employment breakdown by level of educational attainment** | **Percent of total** |
|---|---|
| No college | 2.1% |
| 2-year college degree | 8.2 |
| Bachelor's degree | 60.9 |
| Master's or Ph.D. | 28.8 |
| **Engineers with a master's or Ph.D. by size class** | **Percent of total** |
| Very large establishments | 66.2% |
| Large establishments | 25.0 |
| Medium-sized establishments | 5.2 |
| Small establishments | 3.6 |

Survey respondents reported employing a total of 740 scientists. Nearly 51 percent of these were chemists and 17 percent were physicists. All of the scientists were highly educated, with 81 percent having a master's degree or Ph.D. and the remaining 19 percent having a bachelor's degree.

### Exhibit 6.13: Education of Scientists

| **Employment breakdown by level of educational attainment** | **Percent of total** |
|---|---|
| No college | 0.3% |
| 2-year college degree | 0.0 |
| Bachelor's degree | 18.7 |
| Master's or Ph.D. | 81.0 |

Whether they also look for candidates with at least 2-3 years of experience (for certain positions), most of the interviewees reported that, for at least some of their positions, they focus on hiring recent college graduates (dubbed by many of the interviewees as "fresh outs"). Why? First, they're less expensive than more experienced candidates.

Second, respondents also said that the supply of "qualified" recent college graduates is more plentiful than the supply of "qualified" experienced workers. That may be because recent graduates are more likely to be "blank slates" or "open books" who are not already set in specific skills or even specific industries (experienced workers, in contrast, have typically narrowed their focus and developed more niche skill sets, which limits the kind of work they can do). Interesting to note, that same phenomenon is largely why interviewees reported a desire for experienced workers with specific skill sets in specific types of work (and reported those candidates to be the most difficult to find).

A few interviewees (some of the largest companies) reported minimum GPA requirements for fresh out applicants. Some required a minimum 3.0 GPA, others required a minimum 3.5. To those interviewees, that requirement helps ensure they get the best of the best, the "A" graduates, though it necessarily decreases their pool of "qualified" potential candidates.

### 6.3.3 Specific Skill Sets

Many of the interviewees – both large and small across all industries and all types of technology workers – reported looking for candidates with specific, or niche, skill sets. For many, it is finding candidates with these specific skill sets that is so difficult. See Section 6.6.3 for a discussion of the difficulties interviewees reported in finding specific skill sets, as well as a list of the hardest-to-find skills.

### 6.3.4 Hands-On Experience

Nearly every company reported a desire for job candidates with some type of experience. For some it was three or more years of relevant work experience (see Section 6.3.1) but even for the many firms that hired recent graduates as well, interviewees reported a desire for candidates with some type of hands-on, practical experience – demonstrated success.

One aerospace interviewee said that she "couldn't say enough about the benefit of hands-on experience," including experience gained through internships and part-time jobs. She said that recent graduates who had that kind of experience have performed "markedly" better than new hires with no experience, and that the engineering department at ASU has done a good job with its hands-on programs.

A software interviewee said that "the best candidates either worked part time during school or at least did projects on their own – they *created* something." Another aerospace interviewee said that while the company does hire fresh outs, it wants them to have technical experience. (In addition to being "real smart.")

One semiconductor interviewee said that an understanding of how the business works was critical, which was why he strongly favors candidates with work/internship experience. Many interviewees reported looking for demonstrated ability – whether demonstrated though work experience, internships, or simply on one's own. One software company wants to see that candidates understand not only how the program was built but how it *works*. Another wants candidates that have a foundational understanding of software constructs above knowing particular languages (that's "learning how to learn").

#### 6.3.4.1 Internships

A number of companies reported only hiring recent graduates with experience (including through internships). One semiconductor interviewee, for example, reported that he "rarely" hires fresh outs without internship experience. Another semiconductor interviewee said that only 5-10 percent of their new hires are fresh outs. Among those fresh outs they do hire, they look for people who have internship experience (e.g., test engineering interns from ASU). A software interviewee reported that he doesn't hire fresh outs unless the graduate has interned with the company.

#### 6.3.4.2 Importance of Hands-On Experience with the Latest Technology

A number of interviewees, many of them software companies, emphasized the importance of hands-on experience with the most up-to-date technologies. They emphasized the importance of "staying on the leading edge" and suggested that in the software industry, where technology changes so quickly, knowing particular technologies is far less important than having the foundational knowledge and soft skills necessary to learn the new technologies as they arise.

### 6.3.5 Soft Skills

Many of the interviewees, both large and small, reported looking for "soft skills" in potential hires. Interviewees reported seeking these skills for both high-level and technician-level employees, those with work experience and recent graduates (in other words, everyone). Exhibit 6.14 highlights those soft skills interviewees reported as important.

#### Exhibit 6.14: Soft Skills

| | |
|---|---|
| **Computer scientists** | • Ability to deal with customers<br>• Ability to execute<br>• Communication<br>• Creativity<br>• Entrepreneurial spirit / passion / self starter / self discipline / work ethic<br>• High capacity to learn / raw intellectual talent<br>• Project management<br>• Technical capabilities / savvy |
| **Engineers** | • Ability to collaborate<br>• Communication<br>• Creativity<br>• Flexibility/adaptability<br>• High capacity to learn / raw intellectual talent<br>• Leadership<br>• Problem-solving ability<br>• Self starter / self discipline / work ethic |

#### 6.3.5.1 Why Soft Skills Matter

Interviewees described a number of key reasons why soft skills matter – and why they're important criteria for determining whether a candidate is "qualified." Among those most important reasons:

1) Soft skills cut down on time-to-productivity
2) Candidates with these soft skills are best able to learn new technologies (important in a world where technologies change so rapidly)
3) Soft skills are the hardest to teach

Soft skills can be so important, in fact, that among some IT industry interviewees hiring for technician-level (non-degreed) positions, soft skills override education and experience. One interviewee said that soft skills are hard to teach, but that employees with those "core" competencies could be taught the technical skills.

One IT interviewee said that process management, change management, and project management experience (not really a soft skill but still fits within this discussion) is "sometimes more important than technology experience." He said success is not just in the programming of the software but in its implementation (for that reason, he often sources from consulting firms).

Others, including a semiconductor interviewee, said that soft skills like "high capacity to learn" and "raw intellectual talent" could cut down on time to productivity, making hiring a candidate who doesn't have exactly the right demonstrated experience or niche skills more palatable (in terms of training time and cost expenditure).

When the candidate has a high capacity to learn and clear intellect, "then the employer can be less specific about what the candidate is trained in." What's more, said one software interviewee, in an environment in which technology changes so quickly, soft skills like the ability to learn are more important than technology experience (which grows stale fast).

#### 6.3.5.2 Discerning Soft Skills

A number of interviewees, large and small, reported that they're working to find better ways to discern soft skills in the interview process. One said that he looks to candidates from top universities not specifically because of the hard skills they pick up in programs there but rather because those universities "create a self-screening process" for candidates with the soft skills he's looking for – self starters with confidence.

Another software development interviewee said that his firm judges candidates in a "vigorous interview process." They ask questions about taking learning seriously – to get at that soft skill – though they also do a technical interview to verify technical competency (so "hard" technical skills matter too). "The people who make it through the process are lifelong learners."

### 6.3.6 Foundational Skills

A number of interviewees reported looking for "foundational knowledge," which is different than specific technical skills or knowledge about a specific technology or process. Foundational knowledge, like more specific technical skills, is taught in school (indeed, most programs are based on the premise of providing students with a foundation upon which they build in the workforce).

Some interviewees, particularly those in the software industry, talked about the importance of foundational knowledge and soft skills over specific technical skills in an environment in which technology changes so quickly. One IT interviewee reported using a "T-shaped employee concept" where the firm looks for candidates with exposure across a broad area as well as a deeper dive into a particular area. "Even with specific skills the ability to think broadly is still important," she said.

Another interviewee said that software engineering programs at the universities shouldn't focus on teaching technical languages because "in a world that changes so fast, that kind of knowledge is dead by the time it hits the street." Instead, universities should put more emphasis on the relationship side of software building (human dynamics, behaviors, core business pieces, core systems understanding).

### 6.3.7 Cultural Fit

Two interviewees, one in the IT industry and the other in aerospace and defense, talked about the importance of a job candidate's fit within the company culture. The IT interviewee said that cultural fit was more important than specific skill sets. Both suggested the cultural fit is an important factor for all companies, and all candidates, but that some companies don't articulate it.
One interviewee (who said that attracting the tech workers to meet their demand was "not difficult at all") reported assessing a candidate's cultural fit in a number of ways: through a team interview approach, by asking interview questions designed to assess the candidate's alignment with company core values; and focusing on whether the candidate is clearly passionate about helping small businesses grow. The other looked to specific talent sources (e.g. the military) to find candidates that were more likely to fit well culturally.

## 6.4 Where Are Those Qualified Candidates Coming From?

This section considers where the job candidates that Arizona's technology employers are looking for come from. Survey data includes education of recent grads hired – in-state or out-of-state? (and why) and recent hires who moved from out of state (and why).

### 6.4.1 Other Firms in Arizona

Some interviewees, particularly those in industries in which Arizona has some "concentration" (semiconductor and aerospace and defense), reported hiring experienced workers from other Arizona firms. A number of semiconductor interviewees, in particular, reported being able to source local experienced talent from similar firms that had laid off employees.

"Even if those candidates' experience isn't perfectly aligned, it's still relevant, allowing them to be productive quickly," said one semiconductor interviewee. Indeed, a number of firms in those concentrated industries reported benefiting from the "misfortune" of those companies that have laid off workers, allowing them easy access to experienced engineers who used to work at downsized or closed semiconductor manufacturing facilities. "We get the best of the best who had been laid off," one interviewee said.

The semiconductor interviewees who reported employment of technicians reported that Arizona is the easiest of all places to hire huge numbers (500-600) of technicians at once. They cited as the reason for that ease the other companies in Arizona that employ technicians with similar kinds of skills and experience.

### 6.4.2 Other Firms Outside Arizona

The survey inquired about the extent to which Arizona technology companies hire S&E workers from outside the state. Those surveyed were first asked what percentage of their recent hires had moved to Arizona to accept the job. If the respondent said that less than half had moved from out of state, he or she was asked why. There were two canned responses: there was sufficient local availability; and/or the company had difficulty in getting S&E workers to move to Arizona. The survey also allowed for written responses as to why less than half of the respondent's new hires came from outside of Arizona.

Respondents indicated that 41 percent of the computer scientists they had hired moved from out of state to take the position (see Exhibit 6.15). Large establishments were twice as likely to hire from outside of Arizona as were small or medium-sized establishments. Of the 106 respondents who were asked why less than half of their recent hires had come from out of state, 68 responded that they could find enough qualified computer scientists to hire from the local area. Only 21 of the respondents checked a response stating that they could not get out-of-state candidates to move to Arizona. Respondents were also allowed to provide their own written reasons as to why less than half of their computer scientists came from outside of Arizona. Among the written reasons given, many alluded to the expense of long-distance recruiting and hiring. Only 2 of the 34 written responses indicated that many of the top computer scientists in the nation preferred to work and live in other states, such as California. The report concludes that Arizona technology companies that do not recruit heavily from out of state don't do so more because of the extra expense rather than reluctance on the part of candidates to move to Arizona.

### Exhibit 6.15: Recent Computer Scientist Hires Who Moved from Out of State (Employment Weighted)

| | **Percent of total recent hires** |
|---|---|
| **All establishments** | **40.9%** |
| Large establishments | 50.0 |
| Medium-sized establishments | 23.9 |
| Small establishments | 24.5 |
| **If less than half of the computer scientists you have hired came from outside of Arizona, why is that?** (N = 106; multiple responses permitted)[58] | **Number of responses** |
| There is sufficient local availability | 68 |
| We cannot get computer scientists from outside Arizona to move here | 21 |

According to survey results 39 percent of all engineers recently hired had moved to Arizona to accept the position (see Exhibit 6.16). This is very close to the percentage of out-of-state hires found for computer scientists (41 percent). Again, the results indicate that large and very large employers of engineers are more likely to recruit engineers from out of state than are small or medium-sized employers. 79 respondents said that less than half of their newly hired engineers moved to Arizona from out of state. When asked why, 52 indicated that there was sufficient local availability. There were 16 respondents, or 20 percent of those queried, who said that it was difficult to get engineers from out of state to move to Arizona.

[58] There were 106 survey respondents who indicated that less than half of their recent hires came from out of state.

### Exhibit 6.16: Recent Engineer Hires Who Moved from Out of State (Employment Weighted)

| | **Percent of total recent hires** |
|---|---|
| **All establishments** | **38.9%** |
| Very large establishments | 35.0 |
| Large establishments | 48.9 |
| Medium-sized establishments | 32.2 |
| Small establishments | 28.5 |
| **If less than half of the engineers you have hired came from outside Arizona, why is that?**[59] (N = 79; multiple responses permitted) | **Number of responses** |
| There is sufficient local availability | 52 |
| We cannot get computer scientists from outside Arizona to move here | 16 |
| Other reasons | 23 |

Employers of scientists responded that just over 46 percent of their recently hired scientists moved to Arizona from outside the state (see Exhibit 6.17). This is the highest percentage of out-of-state hires among the three broad groups. Once again, this result is not surprising in view of the large percentage of scientists with graduate degrees.

### Exhibit 6.17: Recent Scientist Hires Who Moved from Out of State (Employment Weighted)

| | **Percent of total recent hires** |
|---|---|
| **All establishments** | **46.4%** |
| **If less than half of the scientists you have hired came from outside of Arizona, why is that?**[60] (N = 17; multiple responses permitted) | **Number of responses** |
| There is sufficient local availability | 8 |
| We cannot get computer scientists from outside Arizona to move here | 3 |
| Other reasons | 7 |

Across the board, interviewees reported that they find it more difficult, and have to look outside Arizona, to find qualified experienced workers (those with more than 3 years of experience) than for recent graduates. Even an interviewee in the aerospace and defense industry said that 80 percent of his newly hired engineers were experienced (they came from other companies) and 75 percent of those came from outside Arizona. "The more highly experienced aerospace engineers came from outside Arizona."

[59] There were 79 survey respondents who indicated that less than half of their recent hires came from out of state.
[60] There were 17 survey respondents who indicated that less than half of their recent hires came from out of state.

One software development firm reported only hiring experienced computer scientists (no recent graduates) and said that there is not a large enough supply of those experienced software developers in Arizona to meet the firm's demand. So the company has to recruit from outside the state (see Section 6.7.2 for a discussion on difficulties, if any, with getting experienced workers to move to Arizona).

Another aerospace and defense interviewee said that the firm "very often" recruits candidates from out of state to come work at its Arizona facilities. A medical device development firm reported that experienced candidates from within Arizona don't have the specific Ph.D. and relevant work experience. That interviewee said he has to recruit from other locations where universities have relevant research departments or train new hires in-house (which he said only makes sense for lower-level engineers and scientists).

Some interviewees, all larger companies with facilities across the U.S., said that they typically offered the best candidates positions at any of their facilities. The interviewees (all hiring managers for Arizona facilities) reported that they were particularly happy when candidates say they don't care where they live – because that allows the company to place those candidates at the location they're most needed. One interviewee reported "competing against itself" in that sense, though he didn't say that it was more difficult to recruit to Arizona facilities than any other facilities around the country.

### 6.4.3 Universities

Many employers, both large and small, reported strong university engagement programs (including recruiting and other types of engagement – see Section 6.5.1). Yet some of the smaller firms reported a lack of available resources for recruiting or other university engagement work. They've all "thought about" working with the universities, or see the theoretical benefit of doing so, but haven't actually done it. One reported being unsure that the "juice was worth the squeeze."

#### 6.4.3.1 "Priority" Schools Outside Arizona

Nearly all of the interviewees – certainly all of the larger firms – reported having "priority" schools where they focus recruiting efforts. Many reported lists of between 20 and 50 schools and said they focus their on-campus recruiting efforts there (especially when money is tight and decisions have to be made about which schools to *not* actively recruit from).

One interviewee said that the company has a "mobile HR team" that goes to job fairs and other recruiting events at universities all over the country. Like a number of the larger employers that aerospace and defense firm said that it recruits for all of its locations across the country, and that recruiting efforts are largely centralized at the national level.

One semiconductor interviewee said that maintaining relationships with universities was a successful strategy for sourcing fresh out talent. He said that he hadn't hired a lot of graduates from ASU, but looks to Auburn and Georgia Tech because they have more electronics-focused engineering programs, where ASU is more general engineering. Exhibit 6.18 highlights the schools that interviewees and survey respondents listed as "priority."

### Exhibit 6.18: "Priority" Schools

| | |
|---|---|
| **Computer scientists** | • Arizona State University (ASU)<br>• Brigham Young University (BYU)<br>• Cal Poly<br>• Carnegie Mellon University<br>• DeVry<br>• Embry Riddle<br>• Georgia Tech<br>• Iowa State University<br>• ITT Technical Institute<br>• MIT<br>• Northern Arizona University (NAU)<br>• Purdue<br>• Rose-Hulman Institute of Technology<br>• Southern Methodist University<br>• Stanford<br>• University of Arizona<br>• University of California at Berkley<br>• University of Cincinnati<br>• University of Michigan<br>• University of San Jose<br>• University of Santa Clara<br>• University of Southern California<br>• University of Texas at Austin<br>• Virginia Tech |
| **Engineers** | • Arizona State University (ASU)<br>• Auburn University<br>• Brigham Young University (BYU)<br>• Cal Poly Pomona<br>• Cal Poly San Luis Obispo<br>• Cal Tech<br>• Carnegie Mellon University<br>• Cornell<br>• DeVry<br>• Embry-Riddle<br>• Georgia Tech<br>• Harvey Mudd<br>• ITT Technical Institute<br>• Kettering University<br>• Michigan State University<br>• MIT<br>• Northern Arizona University (NAU)<br>• Ohio State University<br>• Penn State<br>• Purdue<br>• Stanford |

| | |
|---|---|
| | • Texas A&M<br>• University of Alabama at Huntsville<br>• University of Arizona<br>• University of California at Berkley<br>• University of California Los Angeles (UCLA)<br>• University of California San Diego (UCSD)<br>• University of Cincinnati<br>• University of Colorado at Boulder<br>• University of Maryland<br>• University of Michigan<br>• University of Minnesota<br>• University of Rochester<br>• University of Southern California<br>• University of Texas at Austin<br>• University of Wisconsin<br>• Virginia Tech |
| **Scientists** | • Arizona State University<br>• Brigham Young University (BYU)<br>• Colombia<br>• Georgia Tech<br>• Indiana University<br>• New York University (NYU)<br>• Northern Arizona University<br>• Ohio State University<br>• University of Arizona<br>• University of Buffalo<br>• University of California<br>• University of Cincinnati<br>• University of Iowa<br>• University of Michigan<br>• University of Texas<br>• Virginia Tech |

Other firms reported that they're just beginning to make plans for outreach to universities outside of Arizona. One interviewee said he plans to narrow his list of 50 or so universities to 5 or 6 of the best, where his HR department will engage directly with career services.

###### 6.4.3.1.1 How Do Employers Define "Priority" Schools?

The firms with lists of "priority" schools where they focus their recruiting efforts listed a variety of ways that they create those listed. One aerospace interviewee makes its list of 20 "preferred" schools based on how well their programs align with the company's needs. Another aerospace and defense interviewee said that his CEO creates a list of "top tier" schools from the U.S. News & World Report rankings of top engineering programs.

One large semiconductor firm makes its priority list based on proximity to the location (so both ASU and the University of Arizona made the list, as did the University of California schools), quality

(Stanford, MIT, Carnegie Mellon, Georgia Tech, Michigan State, University of Michigan), and diversity of graduates (the firm emphasizes hiring female engineers).

#### 6.4.3.2 Arizona Schools

Survey data in this section is drawn from questions asked specifically about employees hired who were either new graduates or had less than 2 years of work experience (broadly, "fresh outs"). The survey respondent was asked what percentage of these hires had received their most recent degree from an Arizona institution.

If the respondent indicated that less than half of recent fresh out hires had a degree from an Arizona institution, there was a follow-up question on the reasons why. There were three canned responses that could be checked: 1) Graduates from Arizona institutions do not have the specific skills we need; 2) Few graduates from Arizona institutions apply, or they accept other offers; and/or 3) We have established recruiting relationships with schools outside of the state. The respondent was also allowed to provide written reasons for why less than half of the fresh graduates they had hired came from Arizona institutions.

Survey respondents indicated that only 33 percent of new hires of computer scientists with less than two years of work experience obtained their highest degree from an Arizona college or university (see Exhibit 6.19). Out of 134 respondents identifying employment of computer scientists, 94 said that less than half of the fresh graduates they had hired held a degree from an Arizona institution.

In these cases, respondents were directed in the survey to a question inquiring as to why a relatively small percentage with an Arizona degree had been hired. 16 of these 94 respondents chose a canned response stating that Arizona graduates lacked the necessary job skills. Almost twice as many chose a response which said that they had not received applications from Arizona graduates or that local graduates had accepted jobs with other companies. Of the 94 respondents, 17 indicated that they did not generally hire new graduates from Arizona institutions because they had recruiting relationships with schools outside of the state.

Out of the 94 respondents answering the question as to why such a small percentage of new graduates had been hired from Arizona institutions, 54 gave their own written reasons. In almost all of these cases, the reasons given had nothing to do with the quality or skill sets of Arizona graduates. Many of the respondents simply stated that they only hired people with work experience or that they had not hired at all in recent years. Only 2 of the 54 written responses presented a decidedly negative impression of computer science graduates from Arizona schools. On the basis of both the written responses and the relative infrequency with which the first canned response in this question was checked, there is nothing to suggest that there is widespread dissatisfaction among Arizona technology firms with the quality and skills of computer science graduates from Arizona programs. Indeed, in a survey which made it possible for the respondent to simply check a box to indicate that Arizona computer science graduates lacked the necessary job skills, only 12 percent (16 out of 134) did so.

### Exhibit 6.19: Education of New Grads Hired as Computer Scientists: In State or Out of State?

| | **Percent of total recent hires** |
|---|---|
| **Percentage with a degree from an Arizona institution** | **32.3%** |
| **If less than half of the new grads you hired as computer scientists had a degree from an Arizona institution, why is that?[61] (**N = 94; multiple responses permitted) | **Number of responses** |
| Graduates from Arizona institutions do not have the specific skills we need | 16 |
| Few graduates from Arizona institutions apply, or they accept other offers | 30 |
| We have established recruiting relationships with schools outside of the state | 17 |
| Other reasons | 54 |

A significantly higher percentage of new graduates hired as engineers came from Arizona programs than was the case for computer scientists. Among all engineers hired who were fresh graduates or had less than two years of work experience, nearly 44 percent had obtained their highest degree from an Arizona college or university (see Exhibit 6.20).

There were 75 respondents who said that less than half of the new graduates they had hired as engineers came from Arizona schools. When asked why, the reasons given were similar to those given by the group that had answered the question for computer scientists. 17 of the 75 said that Arizona graduates did not have the skills required. A similar number explained that they had developed recruiting relationships with schools outside of the state.

In the written reasons given for why a respondent had hired relatively few from Arizona schools, most respondents spoke of their need for work experience or mentioned that they had not been hiring recently. Only 2 of the 42 written reasons indicated that Arizona graduates lacked the necessary skills. Overall, for engineers as well as for computer scientists, there is little in the survey to suggest that Arizona technology companies are failing to hire Arizona graduates because of a perceived lack of quality or skills.

[61] There were 94 survey respondents who indicated that less than half of the new grads hired had a degree from an Arizona institution.

### Exhibit 6.20: Education of New Grads Hired as Engineers: In State or Out of State?

| | **Percent of total recent hires** |
|---|---|
| **Percentage with a degree from an Arizona institution** | **43.7%** |
| **If less than half of the new grads you hired as engineers had a degree from an Arizona institution, why is that?** (N = 75; multiple responses permitted)[62] | **Number of responses** |
| Graduates from Arizona institutions do not have the specific skills we need | 17 |
| Few graduates from Arizona institutions apply, or they accept other offers | 24 |
| We have established recruiting relationships with schools outside of the state | 18 |
| Other reasons | 42 |

One aerospace interviewee said that of the 20 percent of new hires that are fresh outs about 30 percent come from Arizona State University and the University of Arizona. He said that the aerospace engineering programs are not as strong at those local schools as at its priority schools.

Another aerospace interviewee echoed a similar sentiment, saying that the company does have a large number of employees who graduated from ASU and Northern Arizona University programs, and that the company "does value in-state schools" but that graduates of top-tier (out-of-state) institutions might have higher-level internship experience than most of the ASU and NAU graduates. (On the other hand, the interviewee said, the "staying power" of Arizona graduates is better.)

Yet another aerospace interviewee said that he "does well" hiring graduates of Arizona's three public universities, which he said have good general electrical engineering and mechanical engineering programs. But he also said that some of the out-of-state schools have better specialty programs, such as the radio frequency (RF) engineering programs at Georgia Tech and Ohio State University. (For graduates of Arizona's more general engineering programs, that interviewee simply trains them on RF in-house.)

On the other hand, the University of Arizona does have one well-known and well-regarded specialty engineering program: the College of Optical Sciences, which interviewees in that field all praised as "one of the best optics schools in the country, alongside the University of Rochester." For that reason, Arizona firms who need optics engineers find a good supply of talent from the U of A.

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[62] There were 75 survey respondents who indicated that less than half of the new grads hired had a degree from an Arizona institution.

### Exhibit 6.21: Education of New Grads Hired as Scientists: In State or Out of State?

| | Percent of total recent hires |
|---|---|
| **Percentage with a degree from an Arizona institution** | **24.7%** |
| **If less than half of the new grads you hired had a degree from an Arizona institution, why is that?** (N = 19; multiple responses permitted)[63] | **Number of responses** |
| Graduates from Arizona institutions do not have the specific skills we need | 6 |
| Few graduates from Arizona institutions apply, or they accept other offers | 6 |
| We have established recruiting relationships with schools outside of the state | 3 |
| Other reasons | 9 |

Of the recently graduated scientists hired by survey respondents, just under 25 percent had obtained their highest degree from an Arizona college or university (see Exhibit 6.21). This was the lowest percentage found in the survey among the three broad groups of technology workers.

That a low percentage of new science graduates had an Arizona degree is predictable given the high percentage of scientists reported with a graduate degree. Graduate training, especially that leading to a Ph.D., is highly specialized. Programs with a particular focus or specialty may exist in only a handful of departments around the country. Arizona establishments interested in scientists with a particular skill set may have little choice but to look outside of the state.

The relatively high percentage (6 out of 19) of respondents indicating that Arizona graduates did not have the skills they were looking for can be interpreted more as a consequence of hiring in a specialized national market than as a judgment about the quality of Arizona programs.

### 6.4.4 2-Year Schools

Very few interviewees talked about hiring out of 2-year technical schools or community colleges. Even among those companies reporting a relatively large number of employees with 2-year degrees as their highest educational attainment, most of those employees came in with at least two years of work experience, rather than fresh out of the 2-year school. Among the firms that did hire recent graduates from Arizona's community colleges and technical schools, they were hiring for technician positions.

One aerospace interviewee, for example, reported working with Chandler Gilbert Community College and the East Valley Institute of Technology to recruit graduates for engineering technician positions. In addition to recruiting, the company works with the schools to drive curriculum. "We tell the schools our requirements so that they can educate students for those skills," the interviewee said. The company also works to increase its "brand awareness" on the local community college campuses, including sponsoring scholarships and donating equipment.

One semiconductor interviewee said that every few years he needs to hire a large number of technicians (500-600 at once right now in Arizona) with at least an associate's degree in electronics engineering or a related technology discipline, or military experience in lieu (see Section 6.4.9). He

[63] There were 19 survey respondents who indicated that less than half of the new grads hired had a degree from an Arizona institution.

said the company often sources recent graduates from technical schools (as well as experienced workers from other companies).

One IT industry interviewee said that the company doesn't currently source recent graduates from 2-year schools but that it does have "an increased interest" in looking at 2-year program schools. The rationale: if technician-level positions could be filled by 2-year graduates as well as (or instead of) 4-year graduates, that would increase the firm's supply pool, and cut down on resource costs (4-years graduates typically demand higher salaries than 2-year graduates do).

### 6.4.5 Internship Programs

Nearly all of the employers interviewed praised the benefits of candidates with internship experience. While firms' willingness/ability to actually host internships and use those internship programs as talent pipelines varied, nearly all firms that have internship programs do see them as strategic talent pipelines. Many of the firms that don't have internship programs want to create them.

Indeed, most of the larger employers as well as some mid-sized and smaller firms reported large and successful internship programs. Many see those internship programs as a "strategic pipeline." One semiconductor interviewee reported that half of his fresh out hires had been interns with the company. He called the internship program a "very strategic source of fresh out hires."

One aerospace and defense interviewee said that "recruiting fresh out engineers amounts to making an intern an offer" (in other words, nearly all of the recent college graduates he hires have interned with him). Another aerospace firm said too that many of their new employees were interns, more from Arizona State University than the University of Arizona. Its internship program, the interviewee said, is a good way to "test drive" students.

Like that aerospace interviewee, most companies reported hiring most of their interns from the Arizona school nearest to them (University of Arizona for Tucson employers and ASU for Phoenix employers). Interviewees from one semiconductor company in Phoenix said that most (though not all) of the firm's interns come from ASU – and that the company "almost always" hires its interns on as full-time employees.

In fact, some interviewees reported that most of their university recruiting efforts focused on filling internship positions (which often then turn into job offers) rather than recruiting for full-time employment directly. One IT industry interviewee said that those efforts are particularly prominent in California, where the company has a "large lab for interns" and recruiters work closely with the local California schools.

Other firms were just beginning to develop their internship programs as strategic talent pipelines. One semiconductor interviewee said that the company was looking to develop its internship program as a true talent pipeline – as a "feeder program" rather than just a source of "summer help." That's another part of the company's efforts to move away from a reliance on experienced workers toward a focus on building fresh out talent within the company (see Section 6.8.1.1).

Still other employers reported seeing the value in internship programs and wanting to do more. One interviewee said that while the company does have internship programs with Arizona's three public universities, the firm's HR department needs to outreach more to its own IT-related business units about the availability of interns and the benefits of using them. He said he'd like to build his own strategic pipeline – getting interns as juniors, having them back as seniors, and then hiring them on after graduation.

A number of respondents reported wanting to take ad hoc sort of internship programs and institutionalize them within the firm. "Most of the interns we get are kids of acquaintances," said one semiconductor interviewee. "We need to have a more structured program, run by an internships coordination department."

Likewise, a software development interviewee said that until recently the firm was focused on fast growth and needed experienced people "with the horsepower to help the firm grow." But now that firm is looking to bring on interns who the firm can then hire when they graduate. This interviewee too said that the company is working on "institutionalizing" an internship program within the company.

Compared to those who have internship programs or plan to develop them, a much smaller number of employers reported a lack of resources for managing interns. One IT interviewee said that the company hasn't used interns extensively because they wouldn't be productive for 9 months.

### 6.4.6 H-1B Visa Programs (for Foreign Nationals)

For a number of Arizona's larger technology employers especially, foreign nationals (people who are not U.S. citizens or permanent residents, but are allowed to work in the U.S. through an H-1B visa) are an important source of technology talent. Even some smaller employees reported that foreign nationals are a crucial source (sometimes the sole source) of highly educated (master's and Ph.D.s) tech talent.

That is true for employers of new or niche types of technology skills, including bioinformatics. But it is also true for more people with high-level degrees and/or work experience in general engineering fields too. One employer of software engineers said, "I can't tell you how many green cards I'm working on."

One semiconductor interviewee estimated that 90 percent of fresh out master's-level applicants for engineering positions are foreign nationals. He joked, "Only one U.S. citizen graduated with a master's degree in electrical engineering last year. And I hired him."

A medical device interviewee said that of the 30-40 résumés he reviewed for a lab director (high-level, experienced) position, not one was a native English speaker (most were foreign nationals, many from China). For many of these firms, regulations prohibit them from hiring foreign nationals; interviewees reported a very clear supply gap when supply is constrained to U.S. citizens (see Section 6.7.4).

### 6.4.7 Workforce Development and Training Programs

Only two interviewees mentioned having experience with Arizona's workforce development and training programs. One, an aerospace and defense employer said that when he needed 30 electronics assemblers (technician-level positions) he worked with the Arizona State Workforce Investment Board, Pima Community College and the now-defunct Grand Canyon Institute for Advanced Studies on a program out of which the company hire about a dozen people, many of whom are still employed there a decade later.

The other interviewee, also in the aerospace and defense industry, had an Arizona Job Training Grant to train managers. The interviewee reported that the program was "incredibly rigid and onerous." It was such a burden to manage, in fact, that the company had to hire an outside firm to administer the program. It's not a something the company would do again, the interviewee said.

### 6.4.8 Contract (Temporary) Agencies

Three interviewees reported hiring contract (temporary) workers from staffing agencies. One large aerospace and defense employer said that the company "relies strongly on contract labor for sourcing, then if the contractor works out we make them a permanent employee." A large semiconductor employer reported hiring a number of "local contractors" as full-time employees. "That's where we're getting the local guys," he said.

The other interviewee, in the IT industry, echoed a similar strategy: the company hires contract workers on a "rent-to-own" sort of basis. The employee is a temporary employee for six months, then providing that it's a good match, becomes a permanent employee. Both interviewees reported this as a relatively risk-free way to source entry-level talent.

### 6.4.9 The Military

Two interviewees, both in the aerospace and defense industry, reported regularly sourcing talent from the military. For one employer, it is a way to find candidates who are more likely to align with the company's military-like culture. For the other employer, it is a way to get candidates who already have some "hands-on" experience with the company's products. Both employers said this strategy is for technician-level positions and that military experience is often in lieu of formal education.

Only one of the interviewees reported interacting directly with the military for recruiting purposes. That interview said he works closely with local military base to get people leaving there (in part because of their relevant experience and in part because they're already used to living in the relatively rural area).

## 6.5 What is the Process by which Firms Source Qualified Talent?

This section discusses the ways that employers find qualified candidates as they're defined in Section 6.3 from the sources described in Section 6.4. Many employers of all sizes reported the importance of proactive efforts to find right-skilled talent. One, from the aerospace and defense industry, said "you can't just run an ad and wait for candidates to call." Making the effort and getting involved, then "it's easy to get 'qualified' people." Another, from the semiconductor industry, said "you can't just sit back and hope things happen. You have to orchestrate talent acquisition."

### 6.5.1 University Engagement

Most of Arizona's technology firms source fresh out talent (recent college graduates) to some extent (see Exhibit 6.8, Exhibit 6.9, and Exhibit 6.10). Many source that fresh out talent from Arizona's universities (see Exhibit 6.19, Exhibit 6.20, and Exhibit 6.21).

But exactly how firms source talent from the universities – the ways in which they "engage" with the state's schools – differs. Many interviewees of all sizes and from all industries reported being involved directly with Arizona's universities at the program level (versus simply attending on-campus recruiting events or even working directly with career services). For some, that involvement means directly working with university departments to shape the curriculum. For others, it's about collaborative projects.

Even one interviewee that has backed off its Arizona recruiting efforts to focus on "priority" schools around the country (see Section 6.4.3.1) still engages with ASU on the program level. The company supports the ASU rocket club (one of the interviewees sits on the advisory board), they're doing an engineering project at ASU Polytechnic, and this summer NASA is paying for two interns from ASU.

#### 6.5.1.1 Connecting Jobs to Students

One interviewee in the medical device industry said that she has developed "strategic partnerships" with ASU and DeVry, letting them know what she's looking for and getting to know the students there. Another interviewee, in the semiconductor industry, reported that he works with ASU professors to "get access to" the best students for internship positions and to monitor the research ASU is doing at the graduate level.

#### 6.5.1.2 Collaborating on Capstone Courses

Capstone course offerings vary from program to program and university to university, but are typically designed to offer graduating seniors a way to integrate their four years of coursework into an applied project – at once demonstrating a foundational knowledge of their major *and* getting hands-on (applied) experience tying that foundational knowledge into real-world applications.

A number of the firms interviewed said that they are directly involved with capstone projects at Arizona's three public universities. One IT industry firm reported working with ASU computer science majors to help create, design, and grade the capstone projects. That interviewee reported that working directly with capstone students "helps a lot" in sourcing right-skilled fresh outs. Another interviewee, in the aerospace industry, reported working directly with the University of Arizona engineering department on capstone projects and plans to "do more going forward to tap those graduates."

Another Tucson aerospace firm also reports being "very involved" with the University of Arizona, where it sources most of its recent graduates. That involvement includes sponsoring 6-month capstone projects (as well as conducting tours of the firm's facilities for U of A students, judging student competitions, and lecturing). That interviewee said he "finds good fresh outs because he's involved with the university."

#### 6.5.1.3 Collaborating on Research and Other Hands-On Projects

A number of interviewees in the science industry reported working with ASU on collaborative research projects. One report using the laboratories at the ASU Technology Center, which the interviewee said works to build strategic relationships between the university and the company.[64]

Another interview reported that his company is "in the process" of formalizing partnerships with ASU so that the company can be an alternative place where Ph.D. students could do research (rather than at the university). The interviewee said that there are "logistical issues" to overcome but that the benefits of a partnership between the company and the university are clear.

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[64] See http://www.asu.edu/tour/polytechnic/tech.html

"A free flow of talent would enrich the company and it would enrich the university. Collaborative science is really important." A third interview in the science field said that he can see the clear benefits of closer collaboration with ASU but that there were technology transfer issues that make collaboration logistically difficult. That interviewee does tap in to university talent now as adjunct faculty at ASU.

The same interviewee said he received an IGERT grant to combine anthropology, bioengineering, physics, math, computer science, and kinesics to look at anatomy in a holistic way.[65] It was an ideal program for generating the kinds of employees that the company needs, but it was run by one professor in the bioengineering department who is no longer there.

"If that professor were still there, we wouldn't have a demand/supply gap," the interviewee said. "Now the pipeline is empty – no one applied to ASU for the biomechanics program because there is no faculty to train them."

#### 6.5.1.4 Shaping the Curriculum

One aerospace and defense interviewee reported that the company gives money to universities to do research and that ASU just started a program to provide training on some of the niche skills the company is looking for (cyber and information solutions). Yet another interviewee from the aerospace industry, one of the largest technology employers in the state, reported that the company "doesn't have enough pull" for the University of Arizona to design a niche skills (radio frequency) training program for them.

A third aerospace and defense interviewee also reported having talked with the state's three public universities about developing aerospace engineering specific programs but said "that's not where the universities want to go; they want to focus on the overall growth of the school and on following megatrends more than serving the local workforce needs."

#### 6.5.1.5 University Recruiting

Most of the firms that reported some or all of the university engagement activities described above also recruited talent directly from the universities. Often, that "traditional" on-campus involves sponsoring (or at least, attending) career fairs, conducting on-campus interviews, and working directly with career services to connect to right-skilled graduates.

In a number of cases, firms reported a lack of resources for the more in-depth kinds of engagement described above. For them, university engagement involves only traditional on-campus recruiting efforts and/or working with career services.

Then there were a number of firms (all small or mid-sized) that reported not having the resources to even engage in university recruiting. Most of those firms, though, do not hire fresh outs anyway though (just candidates with work experience). Only one interviewee that hires a significant number of recent college graduates reported no on-campus recruiting efforts.

Other firms, including a large employer in the aerospace and defense industry, reported recently backing off its active recruiting efforts at the Arizona universities. The company has a "large

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[65] See http://www.igert.org/

population" of employees from ASU and NAU but plans now to focus its recruiting resources on "top tier" schools (see Section 6.4.3.1).

### 6.5.2 Recruiting Agencies (Headhunters)

Many interviewees of different sizes across industries reported using headhunters to find "needle in a haystack" experienced talent with very specific skills. One interviewee in the aerospace and defense industry, for example, reported turning to a recruiting agency when looking for experienced engineers with radio frequency and radiation hardening) experience. Another interviewee said that for very specialized skills or types of experience that were harder to recruit for they engaged specialized aerospace industry recruiters. One interviewee in the semiconductor industry called headhunters "very effective."

### 6.5.3 Job Boards

A number of interviewees, of all sizes and across industries, reported advertising open positions on online job boards like CareerBuilder.com, Monster.com, and even Craigslist as well as in newspapers, journals, on the company's own website, and on the websites of relevant professional organizations.

One IT industry interviewee reported also "concerted sourcing with user groups and networks" of people with the skills and experience the firm is looking for (software developers) in an attempt to resolve its niche skill supply constraints (see Section 6.6.3). The firm attends recruiting events, posts on relevant technology-specific user group websites, and sponsors conferences (such as the Desert Code Camp).

### 6.5.4 Referrals

Many of the interviewees reported finding experienced talent through employee referrals and other referrals. One large semiconductor interviewee said "Most of the experienced engineers we hire from outside of the company come from personal references – and that's worth its weight in gold." An aerospace and defense industry interviewee said the company had a very large referral network of "FBIs" – friends, brothers, and in-laws – which is one of the company's top sources of new hires.

A number of the interviewees, all smaller firms, reported referrals as a part of their "creative" sourcing strategy. Some said their talent acquisition was "100 percent" referral based. One IT industry interviewee said he had recently hired someone who had been working for one of the company's customers. Another recent hire was a sales person for one of the company's suppliers. Still another was the child of a friend. "That way we know the person, have a relationship already."

One biotech industry interviewee reported working to build its referral network among employees to leverage their contact resources. The interviewee said he has been telling the company's employees to put the word out to their collaborators about the kind of talent the company is looking for.

### 6.5.5 Growing Talent from Within (Build versus Buy)

A large number of interviewees at small-, mid-, and large-sized firms in a range of industries reported a focus (for many, a new focus) on growing talent within the company. In some cases, that talent had already been developed by another department or at another location. But in many cases, firms hire recent college graduates, or people with generally aligned (though not perfectly aligned) experience, and train them in-house to the company's specific requirements.

For some interviewees growing talent within the company (what one called a "build versus buy" strategy) is a strategic move. One interviewee, a large aerospace and defense company, said that hiring more recent graduates that the company would then train internally was a "shift in management philosophy" partly the result of cost considerations ("fresh outs typically cost less than experienced employees").

For other employers growing talent from within is simply a "model of necessity" for building up in-house a supply pool that is simply not large enough on its own to meet the firm's demands. For those companies who see "build versus buy" as a strategic move, the reasons why include benefiting from the talent *while* growing it, keeping up with rapidly changing technology, teaching niche skills, enabling rapid growth, reducing reliance on aging workers, and teaching the business.

#### 6.5.5.1 To Benefit from the Talent While Growing It

One IT industry interviewee reported that one advantage of growing talent in-house is the ability to benefit from that talent while it's developing. The company hires employees on for jobs that they're qualified to do (and can be immediately productive at) then encourages those employees to grow and develop new skills at their own pace. It is common, for example, for support desk employees to become application managers (about a quarter of the current application managers followed that path).

Another interviewee, a large employer in the aerospace and defense industry, said that the company CEO wants to increase the number of employees who have master's degrees, and that systems engineering is a big focus. The company can do that, on one hand, by looking for job candidates with those qualifications (and it does) but it can also increase the pipeline of master's-level systems engineers by encouraging existing employees to pursue that kind of education. To that end, the company gives employees $10,000 in tuition reimbursement. And it recently instituted an on-site program through George Washington University and Stevens Institute to graduate nearly 100 employs with master's degrees in systems engineering.

#### 6.5.5.2 To Keep Up with Changing Technology

Many of the IT industry interviewees, especially those involved in software development, talked about how quickly technology changes and how difficult it can be for the curricula (and the professors) in traditional programs to keep pace with those changes. So in response some have turned to educating to those changes in house. One IT interviewee, for example, reported that he hires "good people" with base skills and experience and then grows them internally to adapt to shifts in the technology.

#### 6.5.5.3 To Teach Niche Skills

One large employer in the aerospace industry reported said that the company hires mechanical engineers fresh out of ASU then "grows them" internally, training on the specific niche skills such as rotor design and drive systems that "you can't go to school for." The same interviewee said "it just makes sense that you would need to train people for very specific skills in-house."

Another large aerospace and defense interview reported that the company created an in-house program with Johns Hopkins to "take engineers and turn them into systems engineers." The company also leverages its current engineers who have the work experience and niche skills to train new hires. Another aerospace interviewee reported the same strategy but added that "it takes time to train fresh out engineers to apply the skills they've learned in school."

#### 6.5.5.4 To Allow Rapid Growth

For firms that faced greater supply constraints among experienced people than recent graduates (and that was most firms) a build-versus-buy strategy is one that will enable faster growth (compared to waiting around for external factors to maybe or maybe not boost the supply of experienced people). For one biotech firm, its speed-enabling build-versus-buy strategy involves training new hires who have the right kind of education (master's-level graduates and those working on a Ph.D.) but not the work experience.

#### 6.5.5.5 To Infuse Younger Talent

A number of firms reported concerns about the aging workforce (see Section 6.8.1). Facing a "perfect storm" of a huge wave of experienced workers retiring in the next half decade combined with a constrained base of qualified supply, a number of firms have doubled down on efforts to infuse younger talent into their workforce.

One aerospace interviewee said that the firm is now focusing on getting new graduates and training them internally before the "old" people – who are the best trainers – are gone. "We're changing the way we work," said the interviewee. "We used to just get senior people, now we're looking to a combination of fresh outs and older, more experienced workers who can mentor the young people." He said that he "merges" fresh outs (who are less expensive, have new ideas, and have more energy) with experienced engineers.

#### 6.5.5.6 To Teach "The Business"

A number of interviewees, across industries, reported a desire for employees who understand not only the technical aspects of their job, but the business as well. That combination is rare to find in recent graduates and even in experienced workers unless their past experience very closely aligns.

The firms that reported the strongest emphasis on technology employees who could understand the business as well tend to focus their development efforts on current employees who know the business and have demonstrated an aptitude for certain kinds of technology. When looking for an SAP software engineer, for example, one interviewee said he couldn't find anyone in town so he looked internally and found someone to train on SAP.

## 6.6 Do Firms Have Difficulty Attracting Qualified Technology Workers? Where Does That Difficulty Lie?

This section tackles first the question of whether employers have had difficulty attracting qualified candidates as they're defined in Section 6.3. Then the report asks, if attracting qualified talent has been difficult, is that difficulty particularly acute for certain qualifications? Or certain sources? Survey data includes responses about difficulty attracting "qualified" technology workers.

Survey respondents were asked to provide their general assessment of how difficult it has been to recruit qualified technology employees to work at their Arizona facility. The responses for computer scientists were distributed evenly around an intermediate response. Twenty-three and a half percent said that it was very difficult; 53 percent that it was somewhat difficult; and 23.5 percent said that it was not difficult at all (see Exhibit 6.22).

Strong conclusions either way cannot be drawn from this distribution of responses. Interestingly, large employers were somewhat more inclined to say that it was very difficult to find qualified computer scientists. For respondents employing fewer than 25 computer scientists, less than 9 percent said that it was very difficult, while almost 32 percent said that it was not difficult at all.

### Exhibit 6.22: How Difficult is it to Attract Qualified Computer Scientists? (Employment Weighted)

| | Percent of all respondents |
|---|---|
| **All establishments** | |
| Very difficult | 23.5% |
| Somewhat difficult | 53.0 |
| Not difficult at all | 23.5 |
| **Large establishments** | |
| Very difficult | 31.1 |
| Somewhat difficult | 41.9 |
| Not difficult at all | 27.0 |
| **Medium-sized establishments** | |
| Very difficult | 9.9 |
| Somewhat difficult | 80.7 |
| Not difficult at all | 9.4 |
| **Small establishments** | |
| Very difficult | 8.6 |
| Somewhat difficult | 59.8 |
| Not difficult at all | 31.6 |

When asked generally about whether it was difficult to find qualified engineers to work at their facilities in Arizona, the respondents indicated that it has been easier to recruit engineers than computer scientists. Across all respondents, only 15 percent found it to be very difficult to find qualified engineers to hire (see Exhibit 6.23). More than twice that, or 33 percent, said that is was not difficult at all to find engineers. In hiring engineers, small and medium-sized establishments were more likely than large establishment to say that it was very difficult to find qualified workers. This is an opposite result from what was found for computer scientists.

### Exhibit 6.23: How Difficult is it to Attract Qualified Engineers? (Employment Weighted)

| | Percent of all respondents |
|---|---|
| **All establishments** | |
| Very difficult | 15.2% |
| Somewhat difficult | 52.0 |
| Not difficult at all | 32.8 |
| **Very large establishments** | |
| Very difficult | 1.4 |

| | |
|---|---|
| Somewhat difficult | 59.1 |
| Not difficult at all | 39.5 |
| **Large establishments** | |
| Very difficult | 17.6 |
| Somewhat difficult | 66.9 |
| Not difficult at all | 15.5 |
| **Medium-sized establishments** | |
| Very difficult | 29.6 |
| Somewhat difficult | 34.6 |
| Not difficult at all | 35.8 |
| **Small establishments** | |
| Very difficult | 45.4 |
| Somewhat difficult | 11.1 |
| Not difficult at all | 43.5 |

When asked about how difficult it is for their Arizona facility to recruit qualified scientists, almost all respondents (87 percent) chose the intermediate response, saying that it is somewhat difficult (see Exhibit 6.24). When hiring in national markets, such as those for Ph.D.-level scientists, recruiting is expensive and an employer is often looking for someone with very specific knowledge and experience. It is certainly not going to be easy to recruit such people. On the other hand, it is a national market, with many scientists looking for new positions. The report authors are inclined to interpret the nearly universal intermediate response to this question not as an indication of national shortages of chemists or physicists, but as an expression of the realities of hiring workers with advanced degrees.

### Exhibit 6.24: How Difficult is it to Attract Qualified Scientists? (Employment Weighted)

| | **Percent of all respondents** |
|---|---|
| **All establishments** | |
| Very difficult | 10.8% |
| Somewhat difficult | 87.2 |
| Not difficult at all | 2.0 |

Exhibit 6.25 highlights interviewees' responses about how difficult it is to attract qualified technology talent, as well as the reasons interviewees gave for that difficulty (see again Section 6.2.2.1 for a discussion of how interviewees were chosen from among the survey respondents). Reports of talent sourcing difficulty appear to have much more to do with demand for very specialized skills and/or very specific kinds of experience, rules employers are bound by, and/or an unwillingness or inability to pay to train recent college graduates than they have to do with pure quantity of technology employees in Arizona.

### **Exhibit 6.25: Interviewees' Reponses to the Question *How Difficult Is It for You to Attract Qualified Technology Employees?*[66]**

| **Interviewee NAICS** | **Type of Tech Employees** | **How Difficult?** | **Reasons for Difficulty** |
|---|---|---|---|
| 334 Computer and Electronic Product Manufacturing | Computer scientists - programmers, network and systems administrators | Not difficult at all | |
| 334 Computer and Electronic Product Manufacturing | Engineers - electrical and electronic; industrial; technicians | Somewhat difficult | Skill sets (test engineers); also can't hire non-U.S. citizens (which dramatically shrinks pool of available fresh outs) |
| 334 Computer and Electronic Product Manufacturing | Computer scientists - software engineers, network and systems administrators | Somewhat difficult | Skill sets; experience; soft skills (gumption/initiative) |
| 334 Computer and Electronic Product Manufacturing | Engineers - electrical and electronic; industrial; mechanical; technicians; optical engineers; applied physics | Very difficult | Soft skills (passionate about being engineers, people leadership skills); can't get people to move to Tucson |
| 334 Computer and Electronic Product Manufacturing | Computer scientists - software engineers | Somewhat difficult | Skill sets (looking for specific skill match - Windows driver development/hardware programming experience); permanent, unrestricted right to work in the U.S. |
| 334 Computer and Electronic Product Manufacturing | Engineers - electrical and electronics; industrial; mechanical; materials science; chemical | Very difficult | Ph.D., master's-level; permanent, unrestricted right to work in the U.S. |
| 334 Computer and Electronic Product Manufacturing | Computer scientists - programmers, software engineers, network and systems administrators, database analysts | Somewhat difficult | Skill sets (database and specific packaged application solutions such as Oracle EBS) |
| 334 Computer and Electronic Product Manufacturing | Engineers - electrical and electronics, industrial, mechanical, technicians | Very difficult | Didn't elaborate |
| 334 Computer and Electronic Product Manufacturing | Computer scientists - software engineers, network and systems administrators, support | Somewhat difficult | Skill sets (firmware, which is a combination of software and understanding of hardware); experience |

[66] Exhibit 6.22, Exhibit 6.23, and Exhibit 6.24 reflect the survey responses to the question "How difficult is it for you to attract qualified technology employees?" for all of the firms interviewed (a subset of survey respondents). In many cases, the survey respondent and the interviewee were different people within a given company.

| | | | |
|---|---|---|---|
| | specialists, test program development | | |
| 334 Computer and Electronic Product Manufacturing | Engineers - electrical and electronics, technicians | Very difficult | Experience (senior-level engineers with more than 5 years of experience in semiconductor design and test activities); analog integrated circuit design experience |
| 334 Computer and Electronic Product Manufacturing | Engineers - technicians, process (chemical and materials engineers), product, reliability | Somewhat difficult | Skill sets (semiconductor processing and packaging), experience |
| 334 Computer and Electronic Product Manufacturing | Engineers - electrical and electronics, industrial, mechanical, technicians, process engineers | Somewhat difficult | Skill sets, experience (medical device) |
| 334 Computer and Electronic Product Manufacturing | Engineers - electrical and electronics, mechanical, guidance, navigation, control, software, propulsion/ordnance, pneumatics | Somewhat difficult | Skill sets, experience (radio frequency, radiation hardening) |
| 334 Computer and Electronic Product Manufacturing | Computer scientists - software engineers, network and systems administrators, support specialists | Somewhat difficult | Skill sets, experience (SAP, database analysis) |
| 334 Computer and Electronic Product Manufacturing | Engineers - electrical and electronics, industrial, mechanical, chemical, materials | Not difficult at all | |
| 336 Transportation Equipment Manufacturing | Engineers - electrical and electronics; industrial; mechanical | Not difficult at all | |
| 336 Transportation Equipment Manufacturing | Computer scientists - software engineers | Not difficult at all | |
| 336 Transportation Equipment Manufacturing | Engineers - electrical and electronics, industrial, mechanical, technicians, others | Somewhat difficult | Didn't elaborate |
| 336 Transportation Equipment Manufacturing | Computer scientists - programmers, software engineers, network and systems administrators, support specialists, others | Not difficult at all | |
| 336 Transportation Equipment Manufacturing | Engineers - electrical and electronics, mechanical | Not difficult at all | |

| | | | |
|---|---|---|---|
| 336 Transportation Equipment Manufacturing | Computer scientists - software engineers (firmware developers | Somewhat difficult | Skill sets/experience (real time embedded systems) |
| 336 Transportation Equipment Manufacturing | Engineers - electrical and electronics, mechanical, technicians, chemical, materials science | Somewhat difficult | Experience (aerospace and defense) |
| 336 Transportation Equipment Manufacturing | Computer scientists - software engineers, network and systems administrators, support specialists, others | Somewhat difficult | Skill sets, geographic location (Fort Huachuca/Sierra Vista) |
| 336 Transportation Equipment Manufacturing | Engineers - electrical and electronics, mechanical, technicians, others | Very difficult | Didn't elaborate |
| 336 Transportation Equipment Manufacturing | Computer scientists - programmers, network and systems administrators, support specialists | Somewhat difficult | Skill sets |
| 336 Transportation Equipment Manufacturing | Engineers - mechanical, materials, design, process | Very difficult | Skill sets, experience (air flows and turbine blades, machining and manufacturing experience) |
| 517 Telecommunications | Computer scientists - software engineers; network & systems; support specialists | Somewhat difficult | Skill sets/experience (telecomm/network specific) |
| 517 Telecommunications | Engineers - electrical and electronics; industrial; mechanical | Somewhat difficult | Skill sets/experience (telecomm/network specific) |
| 517 Telecommunications | Engineers - Cisco Certified Network Associate; VMWare Certified Professional | Very difficult | Experience (industry experience, especially on voice side) |
| 541 Professional, Scientific, and Technical Services | Computer scientists - programmers, software engineers | Very difficult | Lack of qualified talent for new economy; candidates don't have soft skills - don't know how to learn and can't communicate |
| 541 Professional, Scientific, and Technical Services | Engineers - electrical and electronics; mechanical | Very difficult | Skill sets (product development); ability to work within range of industries; ability to work within compressed timelines |
| 541 Professional, Scientific, and Technical Services | Didn't respond to survey (too late) but comments are reflected here as interviewee | | |
| 541 Professional, Scientific, and Technical Services | IBM refused to respond to survey but comments are reflected here as | | |

| | | | |
|---|---|---|---|
| | interviewee | | |
| 541 Professional, Scientific, and Technical Services | Computer scientists - programmers, software engineers, network and systems administrators, support specialists | Not difficult at all | |
| 541 Professional, Scientific, and Technical Services | Computer scientists - software engineers, network and systems administrators, support specialists, others (bioinformaticians) | Very difficult | Skill sets (JAVA)/experience (bioinformaticians with software development skills *and* background in biology or research) |
| 541 Professional, Scientific, and Technical Services | Scientists - microbiologists, molecular biologists, biochemists, informaticians | Very difficult | Skill sets, experience, education (AZ schools produce the right kind of Ph.D. candidates but there are very few and they have a lot of options) |
| 541 Professional, Scientific, and Technical Services | Computer scientists - software engineers | Somewhat difficult | Skills sets, experience |
| 541 Professional, Scientific, and Technical Services | Engineers - electrical and electronics, others | Somewhat difficult | Skill sets, experience |
| 541 Professional, Scientific, and Technical Services | Engineers - bioengineers | Very difficult | Experience and education (Ph.D.s with relevant work experience) |
| 541 Professional, Scientific, and Technical Services | Scientists - biochemists and biophysicists, microbiologists | Very difficult | Experience (specifically on NIH-funded projects) |
| 541 Professional, Scientific, and Technical Services | She didn't fill out the survey but she took time to talk to me | | |
| 541 Professional, Scientific, and Technical Services | Computer scientists - programmers, software engineers, network and systems administrators, support specialists | Not difficult at all | |
| 541 Professional, Scientific, and Technical Services | Engineers - computer hardware engineers | Not difficult at all | |
| 541 Professional, Scientific, and Technical Services | Computer scientists - programmers, software engineers, support specialists, network and systems administrators | Very difficult | Skill sets (software licensing skills for specific products and these skills are not trained in college, SAP), experience |
| 541 Professional, Scientific, and Technical Services | Engineers - electrical and electronics, industrial, technicians, manufacturing, systems engineers | Not difficult at all | |

| | | | |
|---|---|---|---|
| 541 Professional, Scientific, and Technical Services | Computer scientists - programmers, software engineers, network and systems administrators, support specialists | Very difficult | Skill sets, experience |
| 541 Professional, Scientific, and Technical Services | Computer scientists - software engineers | Not difficult at all | |
| 541 Professional, Scientific, and Technical Services | Engineers - electrical and electronics, mechanical | Somewhat difficult | Experience |

### 6.6.1 Work Experience

Many of the interviewees who reported difficulty attracting qualified computer scientists, engineers, and scientists said that difficulty lies in finding workers with experience. One aerospace interviewee said that attracting qualified tech talent was not an issue for the positions that could be filled by recent college graduates, but for candidates with at least 10 years of experience, attracting the right talent was more difficult. He cited two reasons why: first, mobility decreases as people buy homes and begin to raise families (and those are the more experienced workers); and second, the perceived lack of other work opportunities in Tucson (see Section 6.7.3).

Another interviewee, in the instrument manufacturing industry, reported what he called a "bathtub" effect in Tucson, where talented scientists and engineers in the 27-40 age range leave, and the only technology talent left behind are recent graduates from the University of Arizona and older "lifestyle seekers." That's a problem, the interviewee said, because it is the 27-40 year olds who are more innovative and can lead recent graduates.

Another aerospace interviewee said he "can't find enough domestic skilled engineers with experience to grow" and that the challenge will only intensify as the older experienced workers (who were planning to retire in the late 2000s) actually do retire in the next 3-4 years. Yet another aerospace interviewee echoed that concern about talent sourcing in the future, saying that employers will face a "knowledge drain" in 5-10 years as experienced employees retire. In response, the interviewee said, she was building technical competency to have "waiting in the wings."

The interviewees who reported the greatest difficult attracting qualified technology workers were looking for very specific kinds of experience. One interviewee in the medical device industry looks for engineers and scientists with Ph.D.s *and* experience working on projects funded by the National Institutes of Health – criteria that conspire to making finding "qualified" talent very difficult.

In another case, an aerospace industry employer who reported that finding qualified engineers is "very difficult" said that the company is looking for "very specific experience" – engineers who have worked with air flows and turbine blades – because the work the company does is complex and highly specialized.

A few technology employers reported that attracting even experienced technology talent was fairly easy. One, in the semiconductor industry, said that some of his recently hired engineers came from other company facilities in Ohio, California, and Oregon. But even when recruiting locally for experienced engineers, that interviewee said there is a "great" talent pool (he said that's because of a good concentration of semiconductor firms in the Phoenix area).

### 6.6.2 Education

Only a few employers reported a difficulty in finding qualified recent graduates. Certainly interviewees sourced from some schools more heavily than others (sometimes in Arizona and sometimes not) and when confined to recent graduates from only Arizona schools a number of employers did report supply constraints (typically for key skill sets, see Section 6.4.3). But when considering all sources of fresh out supply, employers did not report significant constraints nor, in most cases, did they report particular difficulty in getting recent graduates to move to Arizona.

One semiconductor interviewee who hires mostly Ph.D. (70 percent) and master's-level (20 percent) graduates serves as an important exception: he has found it difficult to source talent with that high level of education. He said "Many Ph.D.s want to become professors rather than work in industry. Operational shift work is not glamorous. Most Ph.D.s want to do R&D or stay in academia."

Some of the interviewees, including software firms and aerospace employers, said that university professors seem "out of touch" with the newest technologies, given how rapidly they change. Those criticisms were not directed at any school in particular. One aerospace interviewee said that because "the mission of schools is to educate students to work, the schools need to know what that work will be."

One software industry interviewee said that education on specific skills is a "constantly moving target" that varies from semester to semester. She said that some curricula are keeping up with those changing technologies, but others are not. "Sometimes it's hard to find qualified talent in emerging technologies."

In some cases, interviewees said it might be their minimum GPA requirement causing supply constraint.
One semiconductor interviewee said the company's GPA requirements are "widely known" and may lead applicants with lower GPAs to self-select out of even applying, so the interviewee never even sees them as candidates.

### 6.6.3 Specific Skill Sets

While specific kinds of work experience is a significant source of difficulty for many interviewees (see Section 6.6.1), so is specific skill set requirements. In fact, many interviewees reporting the most difficulty finding qualified talent were looking for very specific skill sets. These firms aren't looking for "software engineers" or "aerospace engineers" but rather for "SAP software developers" or "aerospace engineers who have 10 years of experience with turbine blades." That's a much smaller talent pool to source from; even companies not reporting general difficulty reported that hiring was *more* difficult for niche skills.

When employers are unable to find technology talent with the right kinds of specific skills, they typically resort to training new hires who come in with just some of the required skills (one semiconductor interviewee said that most new hires had just 10-15 percent of the required skills and had to be trained on the other 85-90 percent). That sort of training typically means slower time to productivity and requires resource expenditures. Exhibit 6.26 highlights those niche skill sets that interviewees reported were particularly hard to find, by category of employee.

### Exhibit 6.26: Hard-to-Find Niche Skill Sets

| | |
|---|---|
| **Computer scientists** | • Database analysts<br>• ERP application management<br>• JAVA developers<br>• MySQL database software developers<br>• QA automation engineers<br>• SAP |
| **Engineers** | • Air flow<br>• High-speed circuit design<br>• Medical device development<br>• Radio frequency (RF)<br>• Semiconductor processing and packaging<br>• Telecom network<br>• Turbine blades |
| **Scientists** | • Genetics<br>• NIH-funded projects |

Many of the software development firms reported a difficulty in finding "niche" developers, including MySQL database developers, QA automation engineers, SAP engineers, and ERP application managers. One IT interviewee said that she has "interviewed everyone in the Valley who does MySQL." In other words, she has totally tapped the local supply. For those niche skills, the firm has found better success in Denver and Iowa.

Yet another interviewee in the software development field said that while it was a bit difficult to find experienced JAVA and QA software developers with 3-5 years of experience, by hiring a headhunter the firm was able to find good candidates. "They're not a dime a dozen, but they're out there," the interviewee said.

A number of firms reported difficulty finding workers with SAP skills and experience. One interviewee said that most SAP hires have been relocated from other countries (see also Section 6.4.6) though many of these employees were already in the U.S. working for other companies (many at consulting firms where the employees have demonstrated success in leadership positions).

One semiconductor interviewee said he finds it difficult to find engineers experienced in semiconductor processing and packaging. That's more specialized than typical semiconductor work, and a lot of it is done in Asia, which means finding experienced talent here in the U.S. is more difficult.

One interviewee in the medical device industry conjectured that her difficulty in attracting specialty engineers was because the skill set they're looking for is unique to the medical device industry and that there aren't many other medical device firms in Arizona from which they can source talent with those niche skills (see Section 6.7.3 for a discussion of the lack of industry concentration in Arizona).

For other firms, the gap between demand for skilled talent and the supply of it was the result of the firm's preference that candidates have both specific skills *and* business experience. One software development firm, for example, looks for candidates that have specific software engineering skills *and* subject matter-relevant experience (in retail or supply chain management, for example) – an admittedly harder-to-find combination (see also Section 6.6.1).

### 6.6.4 Hands-On Experience

For most of the interviewees, a candidate qualified on specific skills sets also must have at least three years of experience (and often much more). Few interviewees reported difficulty finding recent graduates with specific skills (again, as long as the supply of recent graduates includes schools both in and outside of Arizona, see Section 6.4.3 and Section 6.6.2).

One aerospace and defense interviewee said that most of the supply constraint for junior-level employees was associated with radio frequency (RF) experience. His resolution to the constraint was to bring in RF fresh outs from non-Arizona schools where he could and to train engineers from Arizona schools in RF in-house (a strategy he said works well, see discussion Section 6.4.3.2).

Another interviewee that reported hiring recent graduates who have had internship experience still does two years of "post-hire grooming" (on-the-job training) because, as the interviewee said, universities don't provide that level of hands-on experience, in part perhaps because the necessary equipment is very expensive.

While nearly all of the interviewees praised the value of hands-on experience for recent college graduates (see Section 6.3.4) only one said that finding recent graduates with hands-on experience is difficult. That interviewee, in the semiconductor industry, said that universities outside Arizona, more so than Arizona's three public universities, "have the capability to give students relevant hands-on experience." That experience, which "doesn't have to be leading-edge," is invaluable to give recent graduates a jump start on the job.

### 6.6.5 Soft Skills

Some interviewees reported dissatisfaction with applicants' soft skills (see Section 6.3.5 for a discussion of what employers mean by "soft skills"). One large semiconductor employer said "Fresh outs with reasonable academic backgrounds still aren't trained enough in soft skills like communication and leadership." That sentiment was echoed by (among others) a small telecommunications employer who said "Candidates from the university engineering programs don't have soft skills like communication ability."

### 6.6.6 Cultural Fit

Of the two interviewees reporting that cultural fit was an important qualification, one (a large employer in the aerospace industry) reported that their cultural fit requirement constrained supply and made it difficult to get the engineering talent the firm needs.

## 6.7 What Are the Root Causes of that Reported Difficulty?

This section looks at the root causes of firms' difficulty in attracting "qualified" talent in Arizona. What's behind the difficulty in attracting "qualified" technology talent? Here, the report takes the particular difficulties that interviewees reported (see Section 6.6) and explores what might be the *underlying causes* of those difficulties.

Some issues that the report authors initially thought might underlie supply constraints (e.g., "Candidates don't want to move to Arizona"), it turns out, were not significant issues for many firms. In other cases, there were underlying factors that the authors hadn't considered (e.g., "I'm prohibited from hiring non-U.S. citizens") that are in fact a serious impediment for a number of Arizona's technology employers.

### 6.7.1 Quantity Constraints (Simply Not Enough Tech Workers)

Section 6.1 touched on the issue of pure quantity constraint (whether Arizona demand outstrips Arizona supply for computer scientists, engineers, and scientists). When Arizona demand is set side-by-side with Arizona supply, only one interviewee reported true pure quantity constraints. For all of the other firms reporting difficulty attracting "qualified" technology workers there was some more nuanced explanation of their supply/demand gap.

The one interviewee who reported a true pure quantity constraint is one of the state's largest employers. Several years ago the company built a new facility, for which it needed almost a thousand new employees – many of them technology workers at one level or another. The interviewee reported that *even after* considering foreign nationals with H-1B visas, they were still unable to fill all of the positions they had open.

The same firm is facing the same constraint again as it prepares to open another facility. The facility will employ about a thousand people. Clearly not all will be computer scientists, engineers, and scientists, but nevertheless the one-time demand for technology workers will again be huge. In this case a quantity constraint that forces the firm to look outside of Arizona feels unavoidable. It's still an important issue, but it's a far more infrequent occurrence – and thus really a different discussion – than the regular hiring needs (demand) and regular production (supply) of engineers and other technology workers in Arizona.

Another interviewee reported encountering similar temporary constraints when the firm is on an upswing (swings that he said were "natural" in the semiconductor industry). He said that he's working to deal with those temporary constraints by growing talent within the company – training and ramping up talent over an 18-month period so the company is ready for the next upswing.

One aerospace and defense interviewee said that he does not typically find it difficult to attract qualified technology workers but that if he ever needed "many" experienced engineers at one time it would be a challenge. At one point he did; see Section 6.4.7 for a discussion of how this interviewee resolved his supply constraint when he needed to quickly ramp up 30 electronics assemblers. Another aerospace and defense interviewee reported that when the company gets a new contract it has to look for technology workers "desperately." Sometimes, he said, the company hires workers from its other locations to work remotely (as a quick-fix solution until it can bring on new talent on-site).

### 6.7.2 People Don't Want to Move to Arizona

When asked if candidates ever expressed resistance to moving to Arizona, interviewees responded in some cases that candidates were resistant to moving *anywhere* (because of difficulty in selling a house, kids in school, spouse's job, etc.) but very few reported any resistance to moving to *Arizona specifically*. In the few cases when interviewees did report a resistance to moving to Arizona specifically, it was almost always because of a lack of industry concentration (see Section 6.7.3).

For a few, the resistance to moving to Arizona specifically centered on "bad publicity about Arizona's school system." Yet most interviewees (with just one exception) said that they were able to counter that negative perception by giving candidates information on the reality of Arizona's schools (that there are, in fact, many great public school districts as well as private schools).

Firms in a range of industries said they just had to address the perception and provide the factual information about where there are good schools in Arizona. "We need to 'sell' Arizona and show job candidates why this is a great place to be." One firm worked with a relocation company to find ways to counter misperceptions, including explaining the quality of the school districts around the company's office in Chandler.

### 6.7.3 Lack of Industry Concentration in Arizona

A much larger number of interviewees reported a "lack of industry concentration" as the source of resistance to moving to Arizona and, more broadly, as the source of difficulty attracting "qualified" computer scientists, engineers, and scientists. This was true for firms in a range of sizes across industries.

**Why does industry concentration matter to employers?** From the employers' perspective, a larger number of high-tech firms means a larger pool of experienced talent to choose from. "The difficulty in finding creative design engineers is a location issue," said one interviewee. "It isn't a problem in Boston, San Francisco, Chicago, New York because those areas have a plethora of firms with creative people." He added that the benefit of being one of few in Arizona is that there's no competition for customers, but that creates the very significant downside of no local talent pool to tap.

One interviewee in the software industry reported that a lack of a "large, established software presence" in Arizona makes hiring experienced software and network engineers a challenge. She reported sourcing experienced talent from a small number of other software companies in Arizona, but said that she has concerns about the challenges finding experienced, right-skilled employees in Arizona.

She contrasted that experienced with Denver, where she said the company has had an easier time finding qualified talent. She pointed to two potential reasons why:

1) The company has a smaller presence in Denver and has been there a far shorter time; it hasn't yet saturated the market. In Arizona, in contrast, most people with software development skills already know about the company (this is the interviewee who said that she has "interviewed everyone in the Valley who does MySQL").
2) A number of tech companies opened in Denver in the early 2000s then shuttered during the boom, so there is a fairly good pool of unemployed people with the right kind of experience in Denver (one semiconductor interviewee mentioned Denver as well, saying that the city "was high-tech but fell off the map").

One IT industry interviewee said that candidates with application management skills came from all over the country "Arizona is not base for application management jobs." That would be fine, if employees from other states felt free to relocate to Arizona. But a number of interviewees reported that is not the case, in part because the housing crash has limited mobility but also because employees, too, want to work in a state that has a concentration of companies in their industry.

**Why does industry concentration matter to employees?** One semiconductor interviewee, who said that many of his experienced hires some from California where there are more high-tech jobs, explained that from the employee's perspective, a larger number of high-tech firms in California means a larger pool of potential employers, which means more safety. If it doesn't work out at employer A, similar employers B, C, and D are just down the road.

One interviewee in the software development industry said that he has to bring experienced computer scientists in from other states because there are not enough similar companies in Arizona to draw experienced talent from. A medical device manufacturer said the same thing; that "process, mechanical, and electrical engineers are very difficult to source from within Arizona because there are only two similar medical device companies." She added, "People don't want to move here when there are no other similar companies because their upward mobility is then seriously limited."

One interview in the biomedical industry said that some candidates did decline to move to Arizona because there is no other biomedical research firm in the state. "Employees can't just go across the street and get another job here like they can in other places." A Tucson aerospace and defense interviewee had the same general comment: candidates hear that Tucson is a "one-horse town" – that if they don't work at that one aerospace and defense company, they don't work anywhere.

In other cases, it's not the perception that Arizona is a "one-horse town" but rather the lack of a "cool factor." One semiconductor interviewee said that one reason why talent goes to the San Francisco Bay area, for example, is because of the perception of a concentration of "cool" companies to work for. That sentiment was echoed by a number of other firms across industries. "People just don't see Phoenix as a hotbed for technology."

One semiconductor interviewee said that there are "decent players" in the high-tech industry in Arizona but that the state is not a "high-tech mecca." Top employees want to go to that high-tech mecca where they have a number of employment opportunities, he said. "Where they can work somewhere else after us."

**Where *is* the concentration in Arizona**? Interestingly, a number of interviewees outside of aerospace and defense and semiconductors listed those industries as relatively concentrated in Arizona. Yet many of the aerospace and defense and semiconductor interviewees themselves reported the same "lack of industry concentration" challenges the other firms did.

One large semiconductor firm, for example, cited "just a handful of companies in Arizona with these kinds of semiconductor experience." One large aerospace and defense employer said the same thing.

One aerospace interviewee, who freely acknowledged that Arizona "has great space presence" said that even more could be done to develop Arizona as an aerospace hub. That development, he said, will come in time ("Arizona is still young"). The same interviewee talked about the importance of university/business collaboration in the development of Arizona's aerospace industry. He also talked about the "huge ability" of the state's larger aerospace companies to "jump-start" Arizona's high-tech workforce.

### 6.7.4 The H-1B Issue: The Candidates Might Be "Qualified" But We Can't Hire Them

A number of firms are prohibited from hiring employees who are not U.S. citizens (or, in some cases, permanent residents). This is true particularly for firms in the aerospace and defense industry as well as others doing military-related work, and even some in the semiconductor industry.

Other companies doing government contract work are not *prohibited* from hiring foreign nationals but rather simply required to "fully consider" U.S. citizens and permanent residents before foreign nationals – not for security-related reasons but to ensure employment of U.S. persons.[67] Still other firms, especially the largest firms with national footprints, impose those requirements on themselves.

Other interviewees who said they were generally free to hire foreign nationals said they are nevertheless constrained by U.S. rules on hiring workers from "controlled" countries (including China) to work on sensitive intellectual property.[68]

When considered against the backdrop of the national origin of technology workers in the U.S. (more than half of all Ph.D. engineers are foreign born) it's clear why firms that are prohibited from hiring foreign nationals find much tougher supply constraints for the higher-level positions (requiring higher levels of education) than other firms do.[69]

One aerospace and defense firm said that the fact that it can only hire U.S. citizens (no candidates with H-1B visas) is becoming an increasingly hard-to-deal-with constraint as "U.S. citizens are not going into engineering programs at the same rate foreign nationals are." The company's response is to do what it can to help increase the number of U.S. citizens in the engineering talent pipeline (see Section 6.8.2.3).

#### 6.7.4.1 Waning U.S. Interest in Science, Technology, Engineering, and Math (STEM)

An inability of firms to hire non-U.S. citizens wouldn't be an issue if there were enough U.S. citizens graduating (particularly at the master's and Ph.D. levels) with degrees in computer science, engineering, and science. Even when a firm's constraint is for workers with at least five years of experience, each of those experienced workers was a recent graduate at some point. So the way to increase the supply of experienced workers is to increase the number of people who graduate with STEM degrees and go to work in STEM fields.

Are foreign-born students graduating with STEM degrees and then going to work in STEM fields at a higher rate than U.S. citizens? In many cases, yes. See Chapter 2 for an in-depth discussion of those trends.

**But why are foreign-born students going into technology fields at a higher rate than U.S. students?** Questioning why there are so many (relatively speaking) foreign nationals in STEM fields

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[67] See U.S. Department of Labor at http://www.dol.gov/compliance/guide/h1b.htm for a discussion on H-1B quotas and hiring regulations (including first looking to U.S. citizens and permanent residents).
[68] See U.S. Bureau of Industry and Security (BIS) at http://www.bis.doc.gov. Individual companies may also have their own additional country classifications and corresponding restrictions.
[69] See Chapter 2.

in the U.S., one multinational semiconductor firm responded "That is a basic education problem. K-12 programs in the U.S. are not funneling kids to STEM at the university level."

Of the interviewees that reported needing to look to foreign nationals as a source of technology talent, many suggested that the reason behind that phenomenon is a waning interest in STEM fields from elementary school through universities among American children. Another semiconductor interviewee said "interest in STEM is waning from college kids."

Some interviews suggested that science, technology, engineering, and math simply isn't as "cool" as, say, high finance. One interviewee said "The U.S. suffers from defective promotion of STEM foundational knowledge because the country's 'prestige' is in banking." Economists speculating on the reasons for the declining frequency with which U.S. citizens are entering S&E fields always note the declining financial rewards, a point which is given a lot of attention in Chapter 2.

In response to supply constraints made more difficult by an inability to hire non-U.S. citizens or permanent residents, some firms are working to increase the number of U.S. citizens in the engineering talent pipeline. One aerospace firm financially supports educational programs that promote science and math, including programs at the local elementary, middle, and high schools, and the ASU Devils Rocket Clubs.

**The bottom line?** Policymakers will either need to change the rules governing firms' hiring of foreign-born technology workers (where rules prohibit their employment on military-related projects) or policymakers, business leaders, and educators together need to figure out a way to drive more U.S. kids into STEM fields. (Or maybe both.)

The interviewee at one of the largest aerospace firms said "There are enough people here in the U.S. that we can supply all the technology workers we need; we don't need to import them from other countries. If only students would pursue technology-related disciplines. The U.S. needs a visionary like JFK to get people to accept the vision of a technology-driven economy, fueled by American computer scientists, scientists, and engineers and then say "How can I help us achieve it?'"

## 6.8 What Are Potential Solutions?

The scope of this study was a very comprehensive assessment of the supply of and demand for computer scientists, engineers, and scientists in Arizona. The scope does not include making policy recommendations for what could be done if a supply/demand gap exists. The report doesn't endeavor to do that in this section. Instead, the report relates some of the ideas that interviewees offered as solutions to the difficulties they have faced in attracting "qualified" technology talent. *These are recommendations made by interviewees, not by the authors of this report.*

These ideas are centered on two solutions-oriented questions:

1) If you had a magic wand and could do anything to resolve the difficulty you have in attracting qualified technology talent, what would you do? This includes what the firms themselves might do to make attracting qualified technology talent easier.
2) If you were sitting at the table with Arizona's top policymakers and the heads of the computer science, engineering, and science departments at the state's educational institutions, what would you ask them to do to make it easier for you to attract qualified technology talent?

In this section, the report explores interviewees' responses to those questions.

### 6.8.1 What Might Companies Do to Address the Talent Sourcing Difficulty?

While many interviewees were eager to suggest ways that policymakers and university leaders could make technology talent sourcing easier, a number of them also suggested actions that they could take (and in some cases are already taking).

#### 6.8.1.1 Realign the Recent Graduate/Experienced Worker Ratio

A number of interviewees said that they were changing their policies (implicit or explicit) which had in the past emphasized hiring experienced workers over recent graduates. More companies are now focusing on "new blood" – recent college graduates that they hire, train, and then promote from within.

One semiconductor firm is changing its recent graduate vs. experienced worker policy. The interviewee said the company (like many others) is "recovering from decades-long behaviors" of replacing a worker who had 10 years of experience with another worker who had 10 years of experience rather than hiring "new blood." Now, the firm is hiring recent graduates into entry-level positions and promoting internally.

The same interviewee said the new policy represented a "big shift" in the way the company sourced technology talent. He cited a number of benefits of a "build talent" strategy over a "buy talent" strategy, including:

- Fresh out talent is less expensive
- There is less competition for each recent graduate
- There is a bigger supply of fresh out engineers
- It helps solve some of the aging workforce issues

Some interviewees who reported similar strategy shifts said their impetus was the coming retirement wave. "We need more people to fill the ladder," said one aerospace and defense interviewee. Another interviewee in the same industry actually called it an "impending talent battle" set to hit in 3-5 years. "Every aerospace firm faces the same wave of retirement. When the wave hits, competition for the remaining experienced workers will become fiercer," he said.

Indeed, that interviewee named its aging workforce as one of the company's "biggest problems." He reported preparing for the looming battle by

1) Codifying knowledge with knowledge management documents
2) Mentoring – placing junior engineers with senior engineers
3) Offering senior workers flexible schedules and part-time retirement options

#### 6.8.1.2 Change Job Requirements

In the high jump, officials progressively increase the height of the bar until no competitor can clear it. If they start with the bar too high – and no competitor can clear it even in the first round – it seems obvious that they would lower the bar and reset the competition.

So it makes sense that if technology employers cannot attract qualified workers, one smart option is to change qualifications. Of course, this must be done in balance with the firm's clear need to hire talented, productive employees. But a number of firms did report at least giving consideration to, for example, lower minimum GPA requirements.

One semiconductor interviewee, who employs a large number of technicians, also reported that the firm is considering changing the job requirements for its technician positions. They're asking "Are these skill sets and experience levels really what is needed to get the job done?" They're also considering changing their pre-hire assessments to better find candidates without technical backgrounds that will be productive employees ("Is there some other reasonable qualifier beside technical background?"). They're treading carefully, though, as they know that changes to qualification requirements can impact productivity down the road.

The same semiconductor interviewee reported considering similar changes for higher-level employees as well. "Maybe we keep our relatively strict requirements but ease them – lower our expectations – when supply is constrained," the interviewee suggested. "That way we're making hiring requirements dynamic based on the market environment."

### 6.8.2 What Might Policymakers Do to Address the Talent Sourcing Difficulty?

#### 6.8.2.1 Incentivize Employers in Arizona's "Core" Industries to Locate Here

In response to a lack of industry concentration in Arizona, which a number of interviewees reported as a root cause of hiring difficulty (see Section 6.7.3), some suggested that Arizona "decide what it wants to be when it grows up;" then make policies to promote those key industries. Yet even firms in those industries that most people would consider "concentrated" in Arizona (aerospace and defense and semiconductors) reported the need for stronger concentrated industry development.

One large aerospace and defense interviewee said that he hopes one outcome of the aerospace and defense commission is a focus on aerospace as a key industry in Arizona.[70] "I'm concerned that Arizona doesn't recognize the importance of aerospace here," he said. He pointed to California as an example of what not to do. "California neglected the aerospace industry, so there's almost no one left there."

In contrast, another interviewee, in the medical device industry, said "If Arizona wants to grow beyond aerospace and semiconductors then it needs to put programs in place to attract other kinds of engineers." She added that "businesses should highlight the kinds of engineers they need and the state should put together programs to attract those people."

Other interviewees suggested that the state play up the assets it already has – beyond sunshine and golf. One said that as long as policymakers and businesses promote Tucson as a lifestyle destination then they won't build a high-tech talent pool. Instead, he suggested promoting University of Arizona for its top optics program. He added that Arizona already has an aerospace and defense cluster and a budding green energy industry ripe for development.

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[70] The Aerospace and Defense Commission is Arizona's sole coordinator of all aerospace and defense related commercial partnerships. The Commission was established pursuant to A.R.S. §§41-1561, 41-1562, 41-1563 & 41-1564. See http://www.azaerospace.com

If the state wants to grow the aerospace and defense industry, one interviewee said, policymakers and business leaders need to court acquisition executives at NASA, the Air Force, the Army, the Departments of Defense, Security, and Commerce – all the organizations with "buckets of money" – and educate them about why they should invest in Arizona. "Look at why Alabama grew so fast as a defense hub," he said. "When the federal agencies move in, then industry follows."

One interviewee, from a small high-tech design company, suggested that the state work with existing firms to "be a catalyst for attracting other firms." He pointed to the clusters in Silicon Valley where existing firms "help bring other companies in that will further develop the cluster." Arizona, he said, "Doesn't have that."

Another aspect of the high-tech clusters that some interviewees praised was the *culture of innovation* they foster. One interviewee said that in order to be a high-tech "mover and shaker" Arizona needs to develop that kind of culture. "Arizona needs an open source network of idea thinkers combined with people who will propel those ideas into the marketplace."

A software development interviewee said that "politicians thwart business development in Arizona" but that they could instead create incentives that would encourage both employees and employers to locate here. He said that Arizona needs to become less dependent on the service industry and real estate and foster a deeper industry base with "credible jobs that attract talent."

Focusing on one or a few key industries makes sense on one had because developing a biotechnology industry likely necessitates a different strategy than building a stronger aerospace and defense industry. On the other hand, some interviewees suggested, policymakers should foster flexibility and let the market determine industry concentration. "Incentivize businesses to build physical wealth and knowledge in Arizona and that will pay for the incentives over the long term," suggested one interviewee.

#### 6.8.2.2 Better Align Workforce Training Programs to Employers' Needs

Most interviewees didn't know anything about Arizona's workforce development and training programs (see Section 6.4.7 for a full discussion of the extent to which interviewees reported sourcing from these programs). Yet it's quite conceivable that policymakers could design – and then market – those programs to make a big difference in alleviating some of the employers' supply pains. Perhaps the workforce development and training agencies could help offset the cost of training "new blood" – even tie training grants to incentives for hiring underemployed Arizonans and/or graduates of Arizona's schools (which they do, to some extent and in some cases).

One telecommunications interviewee said that policymakers should look at industries or sectors with significant growth potential (those are the jobs Arizona should want to attract) and then develop training programs to ensure those jobs can be filled in Arizona by Arizonans.

#### 6.8.2.3 Increase the Emphasis on Science, Technology, Engineering, and Math (STEM) Education

A number of interviewees across industries said they would increase the interest level of K-12 kids in STEM programs and retain that interest through undergraduate and graduate programs. Many of the larger employers do have STEM-related programs aimed at doing that (including competitions for K-12 and college scholarships). See Section 6.7.4 for a full discussion of the waning interest of U.S. kids in STEM fields and why employers report that as a significant problem.

#### 6.8.2.4 Counter Misperceptions About Arizona Schools

A number of interviewees who said that they encountered job candidates who resisted moving to Arizona because of a perception of poor-quality schools reported success in challenging those perceptions (see Section 6.7.2). Policymakers at the local and state levels could do the same. One interviewee said "Arizona needs to come out with statistics to combat those misperceptions about the state's education ranking. The state should advertise its assets."

### 6.8.3 What Might Universities Do to Address the Talent Sourcing Difficulty?

#### 6.8.3.1 Align Faculty Resources with Arizona's "Key" Industries

If Arizona does "decide what it wants to be when it grows up" and policymakers focus on promoting key industries, then the universities should align their faculty and their curricula to produce graduates for work in those key industries, interviewees said.

One large aerospace and defense employer said that the University of Arizona has a "world class" planetary science department but that if the U of A and ASU want to build their capabilities in aerospace "then they need stronger aerospace faculty." Another interviewee suggested that Arizona universities should focus more on what Arizona's employers need instead of teaching to broad "megatrends" (see Section 6.5.1.4).

One of the biotech industry interviewees said that if he had a magic wand he would make it easier for firms to establish partnerships with universities. Another aerospace interviewee said he would get state policymakers, universities, and companies to work together to grow key industries (like aerospace) in Arizona.

#### 6.8.3.2 Tailor Curricula to Business Needs

One software development interviewee said that if he had a magic wand he would be more involved with Arizona schools in developing students to be the kind of candidates his firm is looking for. Then the company would hire recent graduates and develop them internally (instead of looking for harder-to-find experienced workers, like they do now).

Some interviewees reported that university professors seem "out of touch" with the newest technologies, given how rapidly they change (see Section 6.6.2). One aerospace and defense interviewee said that his "magic wand" would be to give professors more "real world" experience. Professors would teach more practical skills rather than purely theoretical. Every professor would be required to work in his or her field for the summer.

At the same time, other interviewees across a range of industries reported wishing that the universities would teach soft as well as hard skills (see Section 6.6.5 for a discussion of soft skills) within their technical programs. Some aerospace and defense interviewees said that the universities need to "do a better job" of teaching soft skills, including how to work in a collaborative environment and how to communicate.

One interviewee reported feeling very strongly that the universities aren't graduating computer scientists who also understand business systems. "I can find a coder pretty easily," he said. "I need more than that. I need people who understand the business, the subject matter." He suggested that universities develop a 6-year degree program that combines coursework with hands-on experience in industry – concentrated in one or two business areas.

#### 6.8.3.3 More Hands-On Experience

Most interviewees talked about the importance of having employees with experience (even companies hiring a lot of recent graduates look for internship work experience or in-class hands-on experience, see Section 6.3.4). But here is the chicken-or-the-egg argument: If all firms are looking for experienced workers and not recent graduates, then where do recent graduates get experience?

Most small and mid-sized interviewees said that's the job of the big firms – to take recent graduates and give them work experience. Big firms can do that, these interviewees said, because they have more resources they can put in on-the-job training. Yet interviewees at many of the big firms said that they don't in fact hire recent graduates and train them in-house (though some gave indication that is changing).

So, then, what's a recent graduate to do? A 6-year degree program that included two years of hands-on experience in industry, like the one suggested above, would provide at least first-level experience that could make recent graduates more palatable to firms (less cost to train, less time to productivity).

The coursework/hands-on combination could even be organized like medical school and residencies are, one interviewee suggested. Another interviewee said that if he had a magic wand he would design an education system within which students get two years of formal (in classroom) education then go to work to get the hands-on experience (or, they work at the same time they're pursuing a four-year degree).

One semiconductor interviewee described a rotation process that his former employer (also a semiconductor firm) used to train the most talented engineers and scientists. He suggested the universities could adopt a similar internship rotation program. "We had an engineering rotation program for the most talented fresh-out hires. For one year they rotated through various departments of the company to get a wide range of exposure, then at the end of the year they chose with department/function they liked best."

One IT industry interviewee praised the benefits of the company's work with capstone students and suggested that the universities (they source from ASU in particular) do more work with companies to get students hands-on practical experience with the current technologies. One semiconductor interviewee suggested that universities could provide more hands-on training in specific technologies to master's-level students. "They could offer a handful of classes on test engineering. Yes it requires capital investment in the expensive equipment but it's not impossible."

#### 6.8.3.4 More Help Connecting to Students

Speaking about his plans to "institutionalize" an internship program in the company, one semiconductor interviewee said that it would help if the universities had a list of available students, the kinds of internships they were interested in, and their skill sets. Another interviewee, in the software development field, said that his HR department works with career services at ASU and attends the career fairs there, but that ASU "does little to help graduates" reach out to HR departments.

**Bottom line?** Again, the scope of this study does not include making policy recommendations for what could be done if a supply/demand gap exists. Yet the interviewees offered a number of ways they themselves could relieve their difficulty in attracting qualified technology employees; ways that policymakers could make it easier to attract qualified technology talent in Arizona; and ways that the universities could produce the kind of technology talent that firms demand.

While not construed to be policy recommendations, these suggestions – alongside suggestions from career services professionals at the three public universities and community colleges (Section 5.2.3), combined also with the advice from workforce development and training professionals in Arizona (Section 5.3) – could certainly facilitate policy recommendations for what can be done (if anything is to be done at all).

# 7 Conclusions

## 7.1 Shortages of Technology Workers in Arizona?

A principal objective of this research project was to determine whether high-technology firms in Arizona have been constrained by a low supply of science and engineering workers. A variety of information was assembled to answer this question: national data on wage trends in S&E occupations, state-level data on the earnings of S&E workers in Arizona, information on the flows of new science and engineering graduates from colleges and universities in Arizona and other states, and most importantly, primary data obtained from surveys and interviews administered by the Seidman research team to Arizona high-technology companies.

Economists look at wage growth as an indicator of labor scarcity. On a national level, statistics from government sources show that wages and salaries of scientists and engineers have lagged behind those in other occupations requiring a high level of training and education. Inflation-adjusted U.S. wages in science and engineering occupations fell during the 1990s. Since 2000, wage increases in S&E occupations have been faster than the rate of inflation, but they have been slower than the rate of increase in wages earned by people in management, health care and other highly skilled occupations. If rapidly rising pay is the primary indicator of a labor shortage, then the country faces more acute shortages of business executives and managers, doctors and pharmacists, lawyers and financiers.

Instead of talking about general labor shortages, it is more accurate to say that the U.S. has an adequate supply of scientists and engineers but only because of a sizeable influx of foreign-born students and technical workers. Over the past several decades, increases in foreign-born S&E workers have offset large declines in the number of native-born male workers. This has been especially true for scientists and engineers with advanced degrees. The U.S. is not experiencing a shortage of scientists and engineers but of native-born entrants into these fields.

Reasons for the decline in the number of U.S.-born males entering science and engineering occupations have been hotly debated. Economists commonly argue that native-born men are simply responding to financial incentives, citing statistics showing that the financial rewards to getting advanced degrees in science and engineering fields have fallen relative to the rewards available in professional fields such as medicine, law and business. It is also possible that the propensity for native-born men to enter science and engineering occupations has declined for reasons other than salary. They may no longer be choosing science and engineering careers because of a preference for other kinds of work or because they are uncomfortable with the rigorous mathematical requirements in these fields.

Companies within a particular state may be constrained by a lack of available technology workers if local educational institutions produce a relatively small number of new graduates. Based on a comparison of the flow of new S&E graduates to the size of the S&E workforce, Arizona is seen to be a relatively low producer of science and engineering graduates. However, virtually all Western states are low producers. In fact, for California, Colorado and Washington – Western states with especially large S&E employment – the ratios of new S&E graduates to employed S&E workers are significantly lower than they are for Arizona. In view of the success these states have had in creating jobs for and recruiting S&E workers, it is clearly not necessary for a state to rely exclusively or even primarily on local colleges and universities to meet its S&E manpower needs.

Companies in a state may also be labor constrained if recruiters have a difficult time getting workers and new graduates to move to their state, either because of a small labor market area, a lack of public services valued by technology workers, or a concentration of firms with government contracts that make it difficult to hire workers who are not U.S. citizens. It is possible to gain some insight into this question by comparing Arizona wages in S&E occupations with U.S. wages. Wages have generally been lower in Arizona than in the nation, in part because of a preference workers have for living in regions with a warm and dry climate. In this case, labor shortages at the state level for a given occupation group may manifest themselves not through wages that are higher in the state than in the nation, but in a state/national wage differential that is higher than the average differential across all occupations.

When looking across all major occupational groups over the past decade, the average ratio of Arizona wages to U.S. wages has been around 95 percent. Ratios of Arizona wages to U.S. wages in computer-related and engineering occupations have been well above this average, although not over 100 percent. Using wages as an indicator of labor scarcity, there is some evidence that companies in Arizona may have faced greater shortages of scientists and engineers than was typical across the nation. Any Arizona-specific shortages of S&E workers have been limited to computer scientists and engineers, however. There is no indication from wage data that the state has faced shortages of workers in life, physical and social science occupations, outside of health care practitioners.

A primary objective of this project was to survey local technology firms to document their hiring practices and recruiting experiences. Follow-up interviews were also conducted to clarify and provide more detail on the survey responses of large companies and a sample of smaller ones. Survey respondents and interviewees were asked about the difficulties they have had finding qualified S&E workers, with particular emphasis on their experiences hiring new graduates from Arizona's colleges and universities and their experiences with out-of-state recruiting.

The survey was especially successful in soliciting information from employers of computer scientists and engineers. A total of 134 establishments reported that they employ computer scientists. Together these establishments employ 6,093 computer scientists, which is approximately 10 percent of total Arizona employment in computer-related occupations. There were 110 surveyed establishments that reported employing engineers. The number of engineers reported by these establishments was 14,426, which is approximately 30 percent of total Arizona employment of engineers.

In the survey, respondents were asked in a general way about how difficult it has been to attract qualified science and engineering workers to fill positions in their companies. There were three possible responses. Attracting qualified S&E workers was: very difficult, somewhat difficult, or not difficult at all. The responses for computer scientists were distributed evenly around the intermediate response. Approximately one-quarter said that it was very difficult; one-half said that it was somewhat difficult; and one-quarter said that it was not difficult at all. It is difficult to draw any strong conclusions either way from this distribution of responses. The frequent choice of the intermediate response "somewhat difficult" can be seen not as an indication of labor shortages, but as an expression of the realities of hiring workers with very specific skills and work experience. The survey results suggest that it has been somewhat easier to find qualified engineers than computer scientists. Among all surveyed employers of engineers, only 15 percent found it to be very difficult to find qualified engineers to hire. More than twice the percentage, 33 percent, said that is was not difficult at all to find engineers.

There was little evidence in either the survey or the interviews of local high-tech employers being dissatisfied with the quantity or quality of new graduates from Arizona's educational institutions. Interviewees repeatedly said that there were sufficient numbers of new graduates available for hire. The problems they had were, in large part, in finding enough experienced workers. With regard to the question of the quality or skills of Arizona's graduates, the survey made it possible for a respondent to simply check a box to indicate that Arizona science and engineering graduates lacked the necessary skills. Of the 134 surveyed employers of computer scientists, only 12 percent said that graduates from Arizona's schools often lacked the necessary job skills. Of the 110 surveyed employers of engineers, only 15 percent checked the box.

With regard to the question of out-of-state recruiting, the survey results indicated that when local technology companies do not recruit heavily from out of state it is more because of the extra expense involved than because of a reluctance on the part of job candidates to move to Arizona. In the interviews, when asked if candidates ever expressed reluctance to moving to Arizona, interviewees responded in some cases that candidates were resistant to moving anywhere (because of difficulty in selling a house, kids in school, spouse's job, etc.), but very few reported a resistance to moving to Arizona specifically. In the few cases where interviewees did report a reluctance to move to Arizona, it was almost always because of concerns job candidates had with the small size of the local labor market. Companies with large defense and government contracts also frequently mentioned difficulties that stemmed from constraints on hiring non-citizens. In a few interviews, resistance to moving to Arizona centered on "bad publicity about Arizona's school system." Yet most interviewees (with just one exception) said that they were able to counter that negative perception by giving candidates information on the high quality of selected public school districts and private schools.

## 7.2 Policy Options

The greatest threat to the viability of high-technology companies in Arizona is the rise of science and engineering capabilities in foreign countries, especially developing countries with large populations such as China and India. The most important policy decision that will affect how firms in Arizona and other states can respond to this threat is immigration policy. If features of U.S. immigration policy, such as the H-1B visa, are further liberalized, it will be possible for many high-technology research and manufacturing activities to remain in the United States. However, if U.S. firms are not able to tap into the world market for scientists and engineers, an increasing number of these activities will go abroad.

For Arizona firms who rely heavily on government and defense-related contracts, an additional important issue concerns restrictions on the hiring of non-citizens. Arizona companies facing these constraints would be favored either by a relaxation of federal hiring standards or special provisions in the naturalization process which expedite the process of gaining U.S. citizenship for foreign-born technology workers or students obtaining advanced degrees at U.S. universities.

Proposals to internally strengthen U.S. capabilities in science and engineering, such as education reforms aimed at improving students' STEM skills, could be productive, especially if they are part of an overall effort to increase efficiency in the public school system rather than a plan supported with resources taken from other areas of education. However, it is unlikely that a significant number of native-born students, especially those pursuing advanced degrees, will begin to choose careers in science and engineering rather than careers in medicine, law, business or finance unless relative financial rewards change. The most likely way in which this would happen is if supplies of new lawyers, MBAs and those with degrees in finance begin to outstrip the demand for these workers. Of course, this would be more of a market outcome than a policy choice.

At the state and local level, there are government policies that could conceivably ease the difficulties firms may be having finding science and engineering workers. In the company interviews, many interviewees cited low industry concentration as a primary handicap to attracting out-of-state S&E workers and supported economic development policies that would strengthen or encourage the formation of high-technology clusters in the state. Economists, however, are generally skeptical of how effective local industrial policies can be (it's not easy to create your own Silicon Valley) and note the general inefficiency of state competition for national industries.

By altering program fees and admission standards, Arizona's universities could encourage more students to obtain degrees in science and engineering. However, this would come at the expense of other degrees which students may prefer or see as having greater monetary value. This report has noted that while Arizona is a low producer of science and engineering graduates, states such as California, Colorado and Washington which have been highly successful in building a high-tech sector produce even fewer S&E graduates relative to the size of their workforce. One constructive change mentioned by many interviewees was for science and engineering departments at Arizona's universities to offer more hands-on training and further promote internship programs.

Finally, there are steps that companies themselves could take to ease labor supply constraints. A number of interviewees said that they were changing their policies which had in the past emphasized hiring experienced workers over recent graduates. More companies are now focusing on "new blood" – recent college graduates that they hire, train, and then promote from within. Some interviewees also mentioned needing to be more realistic about the skill sets needed to get the job done and are considering changing their job requirements.

## Appendix A – The Full Written Survey

**Some notes about the way the survey is presented here:**

- On a number of questions the electronic survey used skip logic so that the respondent's answer to one question directed him to one a follow-on question (or not). The follow-on questions are listed here; places where skip logic is employed are noted with the * symbol.
- After a small set of general information questions in the electronic survey the same set of questions were asked for three categories of employees: Computer Scientists, Engineers, and Scientists. Respondents who employ technology workers in all three categories would see the same set of questions three times, each for the particular category of technology worker. All of the questions are the same for each occupational category; the survey lists them only once here. Where this set of questions begins is noted with the ** symbol.

**<u>General Company Information</u>**

The purpose of this Arizona Technology Workforce Survey is to collect information from Arizona high-technology firms on their skilled labor requirements and their recent experiences with recruiting and hiring skilled labor in Arizona. The survey responses will be combined with information from the state's universities, community colleges and workforce development agencies to assess the balance between supply and demand for technology workers in Arizona.

The focus of the survey is on technology workers. By this we mean professional workers with a Science, Technology, Engineering, or Mathematics (STEM) background. We will ask specifically about Computer Scientists, Engineers and Engineering Technicians, and Scientists.

The information we're going to ask for in this survey includes:

- A profile of your technology workers, including employment counts by occupation and a breakdown of these employees by educational attainment (percent with a graduate degree, percent with a 4year college degree, etc.)
- Information on your hiring experiences over the past ten years, including the percent hired that were recent graduates, the percent that came from out of state, and the percent of recent graduates with a degree from an Arizona institution
- General experience with new hires from Arizona institutions; experiences with out-of-state recruiting

The questions that we ask in the survey are for specific high-technology occupations; we're not looking for HR records, but rather for the experiences and perceptions of hiring managers. To that end, the survey is best completed by the people in your company who manage technology workers. Please note, also, that we are concerned only with your company's Arizona operations and those employees working in Arizona facilities.

This survey should take 15-45 minutes to complete depending upon the size of your organization and the number of technology workers you employ. You can move back and forth between pages using the "Next" and "Previous" buttons at the bottom of your screen. If you leave the survey and come back to it (even on a different computer) any survey pages you have completed will be saved.

If you have any questions as you go through the survey, please contact Molly Castelazo, with the Seidman Research Institute at ASU, at 480-987-7958 or molly@mollycastelazo.com.

**Name of company** ___________________________________________

**Your contact information**
Name ___________________________________________
Job title ___________________________________________
Telephone number ___________________________________________
Email address ___________________________________________

**For larger technology firms, we're asking facility-level managers to complete the survey just for their facility. Are you responding for your facility only or for your entire company?**

- o I am responding just for my facility
- o I am responding for my entire company

***General Information - Company***

**Location of company** ___________________________________________

**Brief description of business activity at your company (e.g., manufacturing semiconductors, biotech R&D, computer integration)** ___________________________________________

***General Information - Facility***

**Location of facility** ___________________________________________

**Brief description of business activity in your facility (e.g., manufacturing semiconductors, biotech R&D, computer integration)** ___________________________________________

**Do you employ Computer Scientists?**

**Do you employ Computer Scientists? (Check all that apply)**

- ☐ I do not employ Computer Scientists
- ☐ Programmers
- ☐ Software Engineers
- ☐ Network and Systems Administrators
- ☐ Support Specialists
- ☐ Other Computer Scientists (please specify) ____________________

***Computer Scientists***

**What is the approximate total number of Computer Scientists you employ in each of the following categories?**
Programmers ________
Software Engineers __________
Network and Systems Administrators _______
Support Specialists __________
Other Computer Scientists __________

**Do you employ Engineers?**

**Do you employ Engineers? (Check all that apply)**

- ☐ I do not employ Engineers
- ☐ Electrical and Electronics Engineers
- ☐ Industrial Engineers
- ☐ Mechanical Engineers
- ☐ Engineering Drafters and Technicians
- ☐ Other Engineers (please specify) ______________________________________________

***Engineers**

**What is the approximate total number of Engineers you employ in each of the following categories?**
Electrical and Electronics Engineers _________
Industrial Engineers _________
Mechanical Engineers ________
Engineering Drafters and Technicians _______
Other Engineers ____________

**Do you employ Scientists?**

**Do you employ Scientists? (Check all that apply)**

- ☐ I do not employ Scientists
- ☐ Biochemists and Biophysicists
- ☐ Microbiologists
- ☐ Chemists
- ☐ Chemical Technicians
- ☐ Physicists
- ☐ Other Scientists (please specify) _______________________________________________

***Scientists**

**What is the approximate total number of Scientists you employ in each of the following categories?**
Biochemists and Biophysicists _______
Microbiologists _____________

Chemists ___________
Chemical Technicians _______
Physicists __________
Other Scientists ____________

**

**Educational Attainment**

**Approximately what percentage of your Computer Scientists (Engineers/Scientists) have as their highest degree attained? (Should sum to 100%)**
No college degree __________
2-year college degree ________
Bachelor's degree __________
Master's or Ph.D. _________________

**Work Experience**

The remaining questions in the section on Computer Scientists (Engineers/Scientists) have to do with your hiring experiences and the workers you have hired over the past 10 years. We are not asking for HR records, but for your closest approximations and general perceptions.

**Approximately what percentage of your Computer Scientists (Engineers/Scientists) were new graduates or had less than 2 years of work experience when you hired them?**
- o 0-24%
- o 25-49%
- o 50-74%
- o 75-100%

**Approximately what percentage of your Computer Scientists (Engineers/Scientists) had between 2 and 5 years of work experience when you hired them?**
- o 0-24%
- o 25-49%
- o 50-74%
- o 75-100%

**Approximately what percentage of your Computer Scientists (Engineers/Scientists) had more than 5 years of work experience when you hired them?**
- o 0-24%
- o 25-49%
- o 50-74%
- o 75-100%

**Alma Mater**

**Among the recent graduates you have hired as Computer Scientists (Engineers/Scientists), approximately what percentage had graduated from an Arizona institution? ("Recent graduates" are new grads or those with less than 2 years of work experience.)**

- 0-24%
- 25-49%
- 50-74%
- 75-100%

***Experiences with Graduates of Arizona Schools**

**Less than half of the recent grads you have hired as Computer Scientists (Engineers/Scientists) were graduates of an Arizona institution. Why is that? Check all that apply.**

- ☐ Graduates from Arizona institutions do not have the specific skills we need
- ☐ Few graduates from Arizona institutions apply, or they accept other offers
- ☐ We have established recruitment relationships with schools outside the state
- ☐ Other reasons (please describe) ____________________________________________

**Residency**

**Approximately what percentage of your Computer Scientists (Engineers/Scientists) were living outside of Arizona when you hired them?**

- 0-24%
- 25-49%
- 50-74%
- 75-100%

***Experiences with Out-of-State Recruiting**

**Less than half of the Computer Scientists (Engineers/Scientists) you have hired came from outside Arizona. Why is that? Check all that apply.**

- ☐ There is sufficient local availability
- ☐ We cannot get Computer Scientists (Engineers/Scientists) from outside Arizona to move here
- ☐ Other reasons (please describe) ____________________________________________
  ____________________________________________________________
  _______

**Recruiting Preferences**

**When recruiting Computer Scientists (Engineers/Scientists), are there particular schools in Arizona that you give preference to? Please list those schools, or enter "none."** ______________
____________________________________________________________
_______

**How about schools outside of Arizona?** ____________________________________________
____________________________________________________________

**Recruiting Preferences 2**

**When recruiting Computer Scientists (Engineers/Scientists), do you look to workforce development programs? Please list those programs, or enter "none."** ___________________________
___________________________________________________________________________________
_____________

**General Difficulty Attracting Tech Workers**

**How difficult is it for you to attract qualified Computer Scientists (Engineers/Scientists)? Check the one that best applies.**

- Not difficult at all
- Somewhat difficult
- Very difficult

**General Difficulty Attracting Tech Workers 2**

**Is that difficulty particularly acute for certain skill sets, experience, or education? Please explain.** _
___________________________________________________________________________________
___________________________________________________________________________________