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America's High-Tech Regions: Route 128 and Silicon Valley

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Silicon Valley and Route 128 are important high-tech regions, or industrial clusters. Route 128 runs around the Boston area, which became the most important site of the early computer industry because of its excellent universities and its close ties to the government. Silicon Valley has never had close ties to Washington, but its dynamic entrepreneurial culture helped it to overtake Route 128 in the 1980s. At present, Silicon Valley is regarded as the world's leading high-tech cluster.

1. Route 128

The Boston area was the most important site of early computer development. Military research played an important role in stimulating the development of electronic and computer technology in Boston. However, the most important reason for the strength of the area's high technology industries is the higher education system. There are 65 universities and colleges in the area, and several, including Massachusetts Institute of Technology (MIT), Harvard, Tufts, and Brandeis, are among the best in the world. Route 128 was built in the 1950s. It helped attract high-tech companies to the area by improving access to MIT and other universities.

MIT played the most important role of any university in the early development of computer technology because it had strong technology departments and close connections to both business and government. In the late 19th century, MIT established the best electrical engineering program in the country. Thomas Edison helped the program in 1887 by donating a large amount of valuable equipment to the electrical engineering teachers. Many of the program's graduates, such as Alfred Sloane, became leaders in the business world.

Around 1910, the university administration began to encourage professors to do research for the government or private firms. The university needed the revenue, but it also believed that interaction between universities and companies was mutually beneficial: Professors and students could help companies to develop new products, and they could also gain a lot of practical experience. Some professors even founded companies. In 1920, Vannevar Bush, an MIT professor, helped to found Raytheon. The company was founded to make refrigerators but soon began making electronics products.

Close ties between Boston universities and the government also promoted the development of Boston area high-tech industries. In 1940, Vannevar Bush became the first presidential science advisor. Bush changed the relationship between the government and science by assigning most

military research to universities instead of government laboratories. After Bush, most presidents (including Truman, Kennedy, Nixon, Ford, and Carter) appointed science advisers from either MIT or Harvard. During the 1940s and 1950s, the government distributed \$330 million for military research to 25 different universities and nonprofit institutions. Of that total, MIT received \$117 million and Harvard received \$31 million.

Military research stimulated the rapid development of high-tech research and industry in the Boston area after 1930. During the 1930s and 1940s, several important research laboratories were founded at MIT to do military research. In 1940, Bush persuaded the American and British governments to move the British radar research team to the US to protect it from the Germans, and MIT provided a laboratory for the team. Raytheon manufactured equipment for the radar project, and developed into a major company. In the 1950s, Raytheon built on its wartime experience to become an important missile manufacturer.

After the war, MIT developed a computer science program, partly to support military research. The most important person in the computer science program was Jay Forrester. Forrester originally went to MIT in 1939 to conduct research on aviation technology. He soon began looking for a machine to speed up the calculation process. Forrester could not find a satisfactory machine, so in 1943 he started the Whirlwind Computer Project. After the war, Forrester persuaded the Pentagon to support Whirlwind as part of a larger project to build a radar system to protect the US from Soviet attacks. Forrester selected IBM to build the new equipment. IBM stopped making mechanical office equipment and became an electronics firm. It hired 8,000 engineers and workers, and delivered its landmark Model 650 to Whirlwind in 1954.

In the 1950s and 1960s, many MIT professors and graduates used their technical knowledge and their contacts with the government to start new companies. A few Harvard professors and graduates also started companies. During the 1960s, at least 175 new Massachusetts firms were created by former employees of MIT's research laboratories and 150 were spun off from Raytheon. At the end of the 1960s, military spending slowed, and Route 128 suffered a severe economic slump. However, Boston's large pool of academic, scientific, and engineering talent continued to attract high-tech companies. The region began to revive in 1975 by focusing on minicomputers.

2. The Birth of Silicon Valley

The three most important factors in Silicon Valley's development have been a strong technological base, military research, and a dynamic entrepreneurial culture. The person who first promoted the development of Silicon Valley was a Stanford professor named Frank Terman. Terman, whose father was a Stanford psychology professor, became interested in radios when he was a boy. He got a BA at Stanford and a PhD in electrical engineering at MIT in 1924. MIT's electrical engineering program was then the best in the country. Before getting his PhD, Terman also gained experience working for a telegraph company. Terman was hired by MIT, but he got tuberculosis and decided to teach at Stanford, where the climate was better for his health.

Terman's ideas about university-business relations were similar to those of the professors at MIT.

He believed that it was important to link universities to industry so that the results of university research and development (R&D) would diffuse to the industrial world. Terman encouraged his students to start up electronics firms, although it was a risky business in the 1920s and 1930s. He used his connections, his influence, and sometimes even his own money to support his students. Two of his most gifted students were William Hewlett and David Packard. Terman helped them with their research and persuaded them to set up a company to market their research. He arranged a bank loan, helped them find work, and loaned them \$538 to start their company, Hewlett-Packard, in 1937. The demand for electronics products created by World War II helped HP and other electronics start-ups around Stanford. HP's sales increased from \$37,000 in 1941 to over \$750,000 in 1945.

After the war, Terman began to strengthen Stanford's program in electrical engineering, using the excellent East Coast programs as his model. Stanford owned a lot of land, and Terman used some of it to create the Stanford Industrial Park (today Stanford Research Park). Terman encouraged high-tech firms to locate their plants in the Park by leasing land at low prices. Hewlett-Packard and the Palo Alto Research Center (PARC) located plants there. Terman persuaded Lockheed to locate a research center in the Park and Stanford professors helped Lockheed to train employees; in turn, Lockheed helped Stanford to strengthen its engineering program. Some firms moved there because they wanted to be near the professors and graduate students. Many Park companies hired Stanford professors and students. By the 1980s, there were 90 firms with about 25,000 workers in the Park. In addition, the concentration of talent and scientific know-how at the Industrial Park encouraged other high-tech firm to establish operations in the Palo Alto area.

Another person who played an important role in the early development of Silicon Valley was William Shockley. A Stanford graduate, Shockley won the 1956 Nobel Prize in physics for helping to invent the transistor at Bell Laboratories in 1947. He left Bell Labs in 1954 because he wanted to form his own company to make transistors. However, Shockley could not get Raytheon to help him establish a company near Boston, so he moved to Palo Alto, partly because his mother lived there. In 1955, he founded Shockley Transistor Corporation in nearby Mountain View. Many young electronics graduates were eager to work for Shockley, and he hired eight of the best in the country. All eight would become important technological innovators and billionaires. The best known was Robert Noyce, who helped invent the integrated circuit in 1957.

Although a brilliant scientist, Shockley was an inept manager and a nasty person. (He later became famous for his racist theories.) He stubbornly insisted on using an old technology even though his young engineers wanted to use silicon to develop new products. In 1957, the eight young engineers left Shockley Transistor and founded a new company, Fairchild Semiconductors. Fairchild quickly became famous for developing the silicon integrated circuit. Equally important, the company also helped to change the region's business culture.

3. The Development of Silicon Valley

A dynamic entrepreneurial culture helped Silicon Valley to develop rapidly. Stanford took the first

step in encouraging electronics firms to locate in the Palo Alto area, and military demand for their products helped them to grow rapidly in the 1940s, 1950s, and 1960s. Since the late 1960s, however, a dynamic entrepreneurial culture has been the most important factor in Silicon Valley's success.

In most dynamic clusters, the entrepreneurial culture encourages people to start businesses, create new products, and take risks. This is true of Hollywood or Italy's textile districts as well as Silicon Valley. The most important elements of Silicon Valley's entrepreneurial culture include a strong interest in technology, intense collaboration, and extensive social networks.

Fairchild Semiconductors helped to establish the entrepreneurial culture. Fairchild was founded by the "traitorous eight" in 1957, but, like Shockley Transistor, it had trouble keeping its most talented and ambitious employees. By 1965, ten new firms had been created by former Fairchild engineers. There were at least 37 semiconductor firms that were direct or indirect spin-offs from Fairchild. The best-known is Intel, founded in 1968. In addition, another "traitor," Eugene Kleiner, founded the region's top venture capital firm.

Social networks encourage the rapid creation of new firms in Silicon Valley. Many of the Fairchild spin-offs, for example, were discussed in a Mountain View restaurant called Walker's Wagon Wheel Bar and Grill, which was popular with Fairchild engineers. Today many business deals are still made in a few popular restaurants. People often change jobs and start companies. About eleven new companies a week are founded. Social networks are a source of venture capital as well as business ideas.

Collaboration is common, even among competitors. Companies routinely borrow staff, share ideas, and exchange favors. Established companies like HP often help start-ups in order to encourage product development and innovation. Most production is outsourced. Outsourcing enables new companies to start up quickly and concentrate on their specialties.

Most people in Silicon Valley are more interested in technology than money. Thus it is relatively easy for people with good ideas to get financing and hire staff to start new companies. Many people hope to get rich, of course, but technological achievements are more respected than wealth.

Social networks help entrepreneurs to start companies, and intense competition encourages ceaseless innovation. Since people often change jobs, companies have trouble protecting proprietary knowledge. Thus they have to keep creating new products to survive.

Social networks were the key to the development of the personal computer (PC). The social network around Silicon Valley in the 1970s included Bill Gates, Steve Wozniak, Steve Jobs, and many other people who helped to create the modern computer industry. Wozniak was a Hewlett-Packard engineer. He gave his plan for a computer to HP, but his boss said the company could not market it and suggested that Wozniak start his own company. In 1976, Wozniak designed the Apple computer in a garage. He and Steve Jobs were then able to found Apple Computer because Mike Markkula, an Intel executive, recognized the potential of the new company and invested \$91,000 in it. In the mid-1980s, PCs overtook semiconductors to become Silicon Valley's most important product.

4. Comparing Silicon Valley and Route 128

Many researchers and journalists have tried to explain why Silicon Valley is such a successful high-tech cluster. Many countries (such as Taiwan and Malaysia) and regions in the United States (such as North Carolina and Austin, Texas) have tried to imitate Silicon Valley. None have come close to matching it. Moreover, Silicon Valley passed up Route 128, America's earliest high-tech sector in the mid-1980s. The main reason that Silicon Valley passed up Route 128 was that it was more flexible. Because it did not have Route 128's close ties to established companies and government, Silicon Valley had to develop new ways of doing things.

Massachusetts has a long manufacturing history that has helped high-tech industries to develop. During the nineteenth century, Massachusetts companies pioneered new manufacturing techniques for firearms, textiles, and other industries. MIT reflected the region's manufacturing tradition. Unlike Harvard, MIT encouraged research and consulting for private industry. In contrast, the Santa Clara Valley was an agricultural region best known for its orchards until the late 1940s.

Both Stanford and MIT encouraged commercial research and tried to get government research contracts. MIT's leaders concentrated on building ties to Washington and to established firms. However, Stanford had few such ties, so it promoted the establishment of new companies and worked with nearby small firms. Around 1,000 companies have spun out of Stanford, including Yahoo! and HP.

Today, the education system around Silicon Valley supports high-tech industry better than the Massachusetts education system. Stanford and Berkeley conduct high-tech research and train engineers. San Jose State also trains many engineers, and six local community colleges provide excellent technical classes. As a result, the Valley produces more technical graduates than any other region in the US. Stanford and the local community colleges work closely with businesses to design new training programs. MIT and other East Coast schools are not as flexible. Close cooperation is especially important to small businesses, which lack the resources to provide long-term training to their employees. Employees at companies in turn often served as consultants and teachers, helping to keep the courses up-to-date. Like Thomas Edison, companies sometimes donate equipment for classes.

Route 128's firms are not as flexible as Silicon Valley's. Many Route 128 firms, such as Digital Equipment Corporation (DEC), are large organizations that specialize in one product. The large firms are mostly autonomous, so they buy few products from small firms. They are also reluctant to exchange information with competitors. In addition, Route 128 became too dependent on minicomputers in the early 1980s. Since the business culture does not encourage flexibility and experimentation, the firms did not adjust quickly when PCs took off. As a result, Route 128 slumped in the mid-1980s.

Silicon Valley companies also used to focus on one product, semiconductors, until they were hurt by Japanese competition in the mid-1980s. However, the tradition of start-ups meant that companies were highly innovative and flexible. Firms began to diversify into more products, especially

computer software. Today Silicon Valley's economy is highly diversified. There are at least seven major high-tech industries, including biotechnology and environmental science.

Route 128 companies embody traditional business values. Large firms prefer stability and loyalty. Management is centralized and hierarchical. Employees tend to have long careers in one firm. Knowledge is internalized in companies, and is not easily available to start-ups.

People in Silicon Valley prefer mobility and change. Management is informal and decentralized. People are more loyal to friends (or to the region, or to the cause of advancing technology) than to companies. Because of social networks, rapid start-ups, and inter-firm collaboration, knowledge diffuses quickly. Firms focus on specialties and buy almost everything from outside suppliers.

Silicon Valley is an excellent example of creative destruction - many firms fail but their people and ideas are used to create new firms. Further, America is very tolerant of bankruptcy. Henry Ford's first two companies failed, for example. Similarly, many of Silicon Valley's successful entrepreneurs have had at least one bankruptcy. The culture rewards risk and does not punish failure. A failed company is considered a learning experience.

Today, Silicon Valley is largely self-sustaining. A large number of engineers and researchers and a well-developed business and financial infrastructure help business to grow. About one third of the world's venture capital, \$5 billion a year, is invested in Silicon Valley, and most of it is raised there as well. In addition, success attracts new talent and capital from other countries. More than 100,000 foreigners, especially from India, Taiwan, Israel, and Europe, help Silicon Valley to remain the world's leading high-tech cluster.

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