Fred Terman Father of the Silicon Valley

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SUMMARY
Silicon Valley, located on the San Francisco, California, peninsula, radiates outward from Stanford University. It is contained by the San Francisco Bay on the east, the Santa Cruz Mountains on the west, and the Coast Range to the southeast. At the turn of the century, when fruit orchards predominated, the area was known as the Valley of Heart's Delight. Today, semiconductor chips, made of silicon, are the principal product of the local high-tech industries. It has been said that an institution is but the lengthened shadow of one great man. Inasmuch as Silicon Valley is an institution, Fred Terman was such a man.

In the 1930's, Professor Frederick Emmons Terman of Stanford University's Department of Electrical Engineering was concerned by the lack of good employment opportunities in the area for Stanford engineering graduates. It troubled him that his best graduates had to go to the East Coast to find employment, especially in the field of radio engineering. His solution was to establish the then-new radio technology locally.

One of his first steps was to bring together two of his former students, William Hewlett and David Packard, founders of the Hewlett-Packard Company.

After World War II, when Terman was dean of the School of Engineering, he was successful in attracting research support from a number of sources. This amount eventually became very large, especially when compared with prewar experiences. Terman was thus able to attract bright new faculty and students.

In addition, he continued to encourage his graduates to start their own companies. Faculty members soon joined in consulting, investing, and, in some instances, founding new companies.

Fred Terman became a legend in his own time. Newspapers and a recently published book have perpetuated a myth regarding his activities: in fact, Terman did not loan William Hewlett and David Packard money to start their company.(Note 1)

The Early Days
Bill Hewlett and Dave Packard hung around the lean Stanford electronics laboratory talking about ``someday'' having their own company.(Note 2) Upon graduation in 1934, however, Packard took a job at General Electric in New York, while Hewlett stayed on for a year of graduate study with Terman before leaving for MIT, where he received a master's degree. Hewlett returned to Stanford in 1936 to work on an electrical engineering degree.

``I did a number of little things then to help get their business started,'' Terman said. ``A new idea in electronics (the so-called `resistance-tuned oscillator') turned up. I told Bill, `It looks to me as if you could use this to make an instrument. It would be a lot simpler and cheaper than anything on the market. But you'll have to solve a couple of problems to make it function.' Bill came up with an absolutely perfect solution. He designed and built an audio oscillator, a device that generates signals of varying frequencies.''(Note 3) To remove serious instability, Hewlett took advantage of the nonlinear resistance-temperature characteristic of a small light bulb.

The addition of one standard and inexpensive component turned a balky laboratory curiosity into a reliable, marketable instrument.

Money was a problem, but by great effort and a bit of luck, Terman was able to get some money together for the project, including a $1,000 grant from Sperry Gyroscope.(Note 4) ``We spent $500 for materials and $500 for Packard's salary. You didn't just get on a plane in those days to hop across the country. In the autumn of 1938, Packard took a leave of absence from his job at GE (which paid $110 a month) to come back here (for $55 a month)."(Note 5)

Packard and his wife rented the lower floor of a duplex, and the two young entrepreneurs went to work in the small garage behind the house. Hewlett moved into a backyard cottage at the same address. Packard later said that after he'd been back three or four weeks, he knew Hewlett was right and that he'd never return to the East. Terman could always tell how the new young firm was doing: ``If the car was in the garage, there was no backlog, but if the car was parked in the driveway, business was good."(Note 6) Their first large order was from Walt Disney Productions. It was for four oscillators to be used in making the motion picture Fantasia.

That modest garage shop housed the beginnings of the Hewlett-Packard Company, which was incorporated in January 1939. Today, Hewlett-Packard is one of the world's largest producers of computers and electronic measuring devices and equipment. It currently employs more than 80,000 people worldwide (22,000 in Santa Clara County) and has sales of more than $6 billion per year.

A Fighter From the Start

Born at the turn of the century, Terman was 10 years old when he moved to Stanford with his parents. The rolling foothills of the Santa Cruz mountains were his playground, and he spent his early teens roaming the hills near Stanford University hunting rabbits and looking for butterflies, turtles and skunks. He fished for bass in Felt Lake and learned to swim in Lake Lagunita (on the Stanford campus). Even as a youngster, Terman had an entrepreneurial instinct; during the holidays, he would collect mistletoe in the hills and sell it to Stanford faculty wives, who were deterred by poison oak.(Note 7)

If Terman had not contracted tuberculosis, he probably never would have joined the faculty at Stanford. The stage was set a young man received his A.B. in chemical engineering and an Engineer Degree in electrical engineering from Stanford. He then headed East to MIT. In those days, Terman recalled, ``a serious young engineer had to go back east to put spit and polish on his education."(Note 8) He earned a Ph.D. in 1924 at MIT under the tutelage of Professor Vannevar Bush.

At the age of 24, doctorate in hand, he returned home to the Stanford campus to spend the summer. He planned to join the faculty at MIT in the fall as a new assistant professor. Instead, tragedy struck; he developed a serious case of military tuberculosis.

Terman spent the next year in bed, with sandbags on his chest. There was no specific treatment for tuberculosis, and sandbags were used to immobilize his chest. (Note 9)

Two doctors abandoned his case at one point, declaring it hopeless, but two other physicians fought to save him. His appendix ruptured in the spring, and he developed eye trouble that was to bother him for several years thereafter.

During his illness, Terman became engrossed once more in radio. As a teenager, he had been a radio ``ham'' and enjoyed experimenting with the fascinating new ``wireless." By age 16 he had his own transmitter, which he used to contact other amateurs as far away as Texas. Lying in bed he had

the opportunity to read Moorcroft's Principles of Radio Communication (Note 10) from cover to cover. He realized he could improve on Moorcroft and set about to do so. While still in bed, he began drafting his first book, Radio Engineering,(Note 11) which was published in 1932. One of his important contributions was the development of ``universal'' curves for representing the selectivity of radio circuits. This technique made possible a great savings in time, and the approach was adopted in the textbooks that followed. (Note 12)

Terman's former advisor, Professor Harris J. Ryan, the head of electrical engineering at Stanford, offered Terman a half-time teaching job at the university beginning in the fall quarter of 1925. Terman gratefully accepted. He spent most of the year in bed, however, getting up only about two hours a day to go to class.

While convalescing, Terman had to learn to conserve his energy; he developed strong work habits and an exceptional ability to concentrate. His friends noted that he could turn his attention on and off at will. A friend once said of him: ``If there are 10 minutes to work on a manuscript, Terman is able to make nine minutes and 50 seconds of it count.''(Note 13)

Professor Oswald (Mike) Villard of the Stanford School of Engineering, a former student and protégé of Terman's, once recalled: ``Along with enormous energy, Terman always had a clear idea of what he wanted to do and what to do to meet his objectives. He was phenomenal in his self-discipline. After spending a full day at the university, he would go home and work on his books.'' When asked if he ever pursued a day without working, Terman replied, ``Why no, how could you ask that question?'' Joseph M. Pettit, one of Terman's best students, and currently president of Georgia Technological Institute, once said: ``Terman never took a year off to write a book. Instead, he used to say that if he wrote only a page per day, he would have a 365-page book by the end of the year.'' Terman worked seven days a week and felt no need for vacations.

``Why bother,'' he once remarked, ``when your work is more fun?''(Note 14)

Terman's health gradually improved, and in 1927 he was appointed assistant professor of electrical engineering. In 1930 he was promoted to associate professor, and in 1937, at the age of 37, he became professor and executive head (now known as chair) of the Electrical Engineering Department.

Beating the Odds

While reminiscing about the early days in electrical engineering, Terman said: ``The Depression years were more difficult than you can imagine. We had nothing, literally nothing, to work with. An accident that burned out a few vacuum tubes or damaged a meter would produce a crisis in the laboratory budget for a month. As an economy measure, I insisted that the laboratory meters be protected by an elaborate system of fuses. Students often chafed at this, because the fuses frequently got blown and it was always difficult to find a replacement of the right size. But the meters survived!'' The prewar electronics laboratory was in an attic under the eaves, over the electrical machinery laboratory. The roof of the attic leaked, and at times these leaks became quite bad. There was no money to repair the roofs, so they built big wooden trays and lined them with tar paper and tar. As the trays filled, we walked around them. Our morale didn't suffer. One winter Bill Hewlett added a homey touch by stocking the trays with goldfish.''(Note 15)

At a testimonial dinner for Terman, Edward Ginzton told about his own arrival at Stanford during the depths of the Depression. Ginzton had graduated in electrical engineering from the University of California at Berkeley in 1936. He estimated that out of about 10,000 students who graduated that

year, two or three had found jobs. Ginzton had unsuccessfully interviewed with 10 big companies, after which he tried the utility companies. He then started walking the streets of San Francisco, where he was living, trying to find any job, but with no luck. ``Finally, the fall came, and I was pretty desperate. I heard that Professor Joseph Carroll at Stanford was looking for an assistant in high-voltage engineering. I came to see him, and he talked to me for a few minutes and realized that even though he had some positions available, I wasn't the right person for his needs." Carroll sent him to Terman. ``I'll never forget the conversation I had with Fred. I was discouraged about life, after walking the streets of San Francisco, and in one hour's time Fred transformed my life from a hopeless, dismal experience to one of excitement and anticipation and looking forward to what might happen in the future. He offered me a research assistantship at $135 per quarter. That made it possible for me to come to Stanford, and I did. People complain that faculty members don't have much time for their students, that they are always traveling, looking for contract support, or whatever, but Fred spent endless hours with us, his students."

Ginzton continued, ``Working for Fred was an unforgettable experience. He taught us a lot, directly and indirectly. He had meager resources within the department, and only one professor, Karl Spangenberg, whom he had brought in. There weren't enough faculties to go around, so he encouraged us to create our own seminars, to teach each other. To be working for yourself, by yourself, along with Fred Terman, arguing with him about problems, helping him write his books it was just an exciting period to be a member of his graduate courses an unforgettable experience."(Note 16)

Terman was instrumental in putting Ginzton in the right place. As Villard remarked, ``Terman could have kept him for himself, but instead he sent him over to Professor William Hansen in physics. It proved to be a stroke of genius." Ginzton had the right combination of organizational and scientific abilities needed to manage technical projects and keep them moving forward.

In March 1939, Ginzton, while still a graduate student, became involved with Hansen and Russell and Sigurd Varian in the development of the klystron tube. He received his Ph.D. in physics in 1940 and spent the war years with the klystron group at Sperry on Long Island. In 1943, when the Variants were making plans to start their own company as soon as the war was over, they invited Ginzton to join them.

In her book, The Inventor and the Pilot, Dorothy Varian says: ``One of the reasons for asking Ed to join the group was to have him manage the company. At that time, he had two years of experience as a project manager at Sperry and was very successful in working with the men in his department. As plans for the laboratory proceeded, his ideas on how to work with others, the kinds of business incentives that might be desirable, and procedures for organizing the company were important to the basic concepts later incorporated into company policy." She continues: ``As the war neared its end in 1945, Ginzton was offered an appointment as assistant professor of physics at Stanford. He discussed this offer with other members of the group, for his proposed role as manager was a crucial one, but they urged him to accept the Stanford appointment. The laboratory was still a year or more in the future, and Ginzton agreed to serve as a consultant on both management and scientific levels."(Note 17)

Varian Associates was organized in 1948. For the 11 years that followed, Ginzton divided his time between teaching and researching at Stanford and consulting on the company's technical projects and serving on its board of directors. After Russell Varian's death in 1958, Ginzton became chairman of the board and chief executive officer at Varian. In 1961, he left Stanford to devote his full

attention to Varian. While continuing as chairman of the board, he served as president from 1964 to 1968 and remained the chief executive officer until 1972.(Note 18)

A Tireless Worker

Terman's friends describe him as a serious man who knew what he wanted to accomplish and who attended to details with the utmost care. He dressed in conservative suits, wore old-fashioned shoes, and always drove second-hand cars. As one friend commented, ``He was not a hale fellow well met," but he did have a sense of humor and an appreciation of odd turns of events. He had no hobbies other than a zestful mania for the doings of the Stanford football team. He was also noted for his keen intelligence. ``He was always three or four sentences ahead of everybody else,'' an admirer once said. ``He was always alive and thinking about problems. He would sometimes telephone late in the evening, long after I'd buried myself in a martini."(Note 19)

In 1965, at a dinner honoring Terman, David Packard reminisced: ``As a student, I became acquainted with Professor Terman before I enrolled in his course. Among my hobbies was amateur radio and I spent a spare hour now and then in the radio shack in the attic of the Engineering Building. Professor Terman's laboratories were next door. Sometimes he would stop to chat for a minute or two. After several such brief visits, I was amazed to find that he knew a great deal about me. He knew my interests and abilities in athletics; he knew what courses I had taken and what my grades had been; and he had even looked up my high school record and my scores on the entrance examinations.

``At that time, Professor Terman had already developed a broad knowledge of and a personal acquaintance with the business and industry related to his academic discipline. He would often tell us about the corporate history, as well as the current activities, of all the important firms in this newly developing industry. Although he had been teaching only a few years, many of his former students were already making important contributions in their new jobs, and he kept in touch with them.

``The highlight of his course for me was the opportunity to visit some of the laboratories and factories in this area. Here, for the first time, I saw young entrepreneurs working on new devices in firms that they had established. One day Professor Terman remarked that many of the firms we visited, and many other firms throughout the country in this field, had been founded by men with little or no formal education. He suggested that someone with a formal engineering education, and perhaps a little business training, might be even more successful."(Note 20)

During the early 1940's, Terman was called upon by Vannevar Bush to head a big defense research project at Harvard University, developing radar countermeasures. The experience put him in the mainstream of government electronic research. The success of the wartime work led him to believe that the government would not allow this work to disappear completely in peacetime. He also felt that it would be appropriate for the government to support fundamental research in universities. There was a widespread feeling at the time that wartime applications had exhausted the supply of fundamental discoveries, and that it needed to be replenished. Accordingly, he set out to expand Stanford's School of Engineering after he returned to the university in 1946 as the dean of engineering. In this capacity, his government contacts helped him to attract federal funding. (Note 21)

As a corporate board member of new young companies and a frequent speaker at industry meetings, Terman took advantage of these opportunities to spread his message. In his words: ``I encouraged our new, young faculty members to get out and get acquainted with local industry and with the people

in it who were doing interesting and creative things. Likewise, I encouraged industry to know their university by getting acquainted with what was going on at Stanford as it related to their own technical interests, and to make the acquaintance of those university people who had similar interests."(Note 22)

Stanford Industrial Park

In the 1950's, the idea of building an industrial park arose. The university had plenty of land over 8,000 acres (Note 23) but money was needed to finance the University's rapid postwar growth. The original bequest of his farm by Leland Stanford prohibited the sale of this land, but there was nothing to prevent its being leased It turned out that long-term leases were just as attractive to industry as outright ownership; thus, the Stanford Industrial Park was founded. The goal was to create a center of high technology close to a cooperative university. It was a stroke of genius, and Terman, calling it ``our secret weapon," quickly suggested that leases be limited to high technology companies that might be beneficial to Stanford. In 1951 Varian Associates signed a lease, and in 1953 the company moved into the first building in the park. Eastman Kodak, General Electric, Preformed Line Products, Admiral Corporation, Shockley Transistor Laboratory of Beckman Instruments, Lockheed, Hewlett-Packard, and others followed soon after.

In 1955, Terman became provost, and three years later he became vice president of Stanford. He transformed the university's Chemistry Department into one of the best in the country. Two outstanding chemists, William Johnson from the University of Wisconsin, and Carl Dieresis, a University of Wisconsin graduate, who had become vice president for research at Mexico-based Syntax Corporation, joined the faculty at Terman's behest. By bringing Djerassi to Stanford, Terman set in motion a whole new chain of company formations in biology and medicine. Largely at Djerassi's urging, Syntex established a U.S. subsidiary and research branch in the Stanford Industrial Park. Djerassi brought Alejandro Zaffaroni, Syntex's executive vice president, with him.

Djerassi and Zaffaroni were responsible for the formation of four new companies Syva, Zoecon, Alza, and Dynapol.(Note 24)

Professor John Linvill, former chair of electrical engineering, credits Terman with attracting him to Stanford. Linvill said, ``He had a remarkable way of keeping track of people. He had contacts all over the place. He knew I had gone from MIT to Bell Laboratories to work on transistors, and he recruited me in 1954 to set up a transistor program at Stanford."(Note 25)

Linvill started his own company with partial backing from the university in 1971. He is now co director of the Center for Integrated Systems, a research center on campus, funded primarily by corporations, that does basic research in integrated systems.

Terman encouraged William B. Shockley, co-inventor of the transistor, to return to his hometown of Palo Alto. In 1956 he established the Shockley Transistor Laboratory of Beckman Instruments where they produced Shockley four-layer diodes. Shockley, who joined the Stanford faculty as a professor of electrical engineering in 1963, said that the decision was made predominantly because of the Bay Area, the fact that there are more trees in the area than there are in Southern California, and Stanford. (Note 26)

However, eight of Shockley's bright young electronics specialists left in 1957 to establish Fairchild Semiconductor in Palo Alto. This was the beginning of the semiconductor industry; Fairchild became

a corporate seedbed as no less than 38 new companies were started by former employees. (Intel is one of the most famous.)(Note 27)

Professor Dean A. Watkins was director of the electron devices laboratory and co director of the Stanford Electronic Laboratories. Terman recognized qualities in Watkins that he knew would make him a good businessman. When people from the Kern County Land Company let it be known that they wanted to invest in a military electronics enterprise based on microwave tubes, Terman told them he had just the right man and introduced Watkins to them.(Note 28)

That was the beginning of Watkins-Johnson, which was founded in December 1957 by Watkins and H. Richard Johnson. Watkins continued on the faculty of electrical engineering as a professor until 1964, and then as a lecturer until 1970.

Johnson was also a lecturer in electrical engineering from 1958 until 1968.

The atmosphere for growth became contagious; Terman continued to encourage his graduates to start their own companies, and faculty members continued to participate in the consulting, investing, and founding of new companies.

The Honors Cooperative Program

Early in the 1950's, at the close of the Korean conflict, the managers of several local firms asked Terman to permit their employees to continue their education on a part-time basis. In 1953, Terman decided that it was possible to accept some additional graduate students without increasing costs greatly.

Companies in the area were notified that they could send qualified employees to regular day-time classes; the workers would be released from their company duties during this time. The response from industry was dramatic, and classes were quickly overloaded. Tuition covered less than half of the actual cost to educate a student. The result was overflowing classrooms and the underpayment of costs.

To solve the problem of maintaining the quality of education, Terman then Dean of the School of Engineering originated the Honors Cooperative Program, in the autumn quarter of 1954. Under this program, four companies (Sylvania, Hewlett-Packard, SRI International, and General Electric) agreed to select a number of qualified employees for enrollment in graduate work at Stanford. The companies signed five-year agreements specifying that they would pay double tuition for each student. This arrangement essentially covered the full cost of educating the Honors Cooperative students. The matching funds were transferred to the departments in which the students were studying and were used to hire additional professors to handle the increased teaching load. (Note 29)

Conclusion

Once when fruit orchards predominated, it was called the Valley of Heart's Delight; it is now called Silicon Valley. Today semiconductor chips, made of silicon, are the principal product of the local high-tech industries. The term Silicon Valley was used occasionally mostly by easterners who would mention making a trip to Silicon Valley, until 1971 when it was popularized in a series of articles, ``Silicon Valley USA,'' written by Don Hoofer for Electronic News. Quite likely it was the first time the term was used in print. (Note 30)

Silicon Valley radiates outward from Stanford University to the adjacent cities of Palo Alto and Menlo Park; northwest to Redwood City and San Carlos; southeast to Los Altos, Mountain View, Sunnyvale, Cupertino, Santa Clara, Campbell and San Jose; and is gradually expanding to Alviso, Milpitas and Morgan Hill. It is contained by the San Francisco Bay on the east, Santa Cruz Mountains on the west and the Coast Range to the southeast.

Approximately 2000 electronics and information technology companies, (Note 31) along with numerous service and supplier firms, are clustered in the area. The valley contains the densest concentration of innovative industry that exists anywhere in the world, including companies that are leaders in such fast-expanding fields as computers, semiconductors, lasers, fiber optics, robotics, medical instrumentation, magnetic recording, and educational and consumer electronics. Some are branches or subsidiaries of bigger corporations that felt obliged to establish research facilities in the area, even though their headquarters may be located elsewhere. Most of the new industry is home grown, however. (Note 32)

Terman once said, ``When we set out to create a community of technical scholars in Silicon Valley, there wasn't much here and the rest of the world looked awfully big. Now a lot of the rest of the world is here."(Note 33)

Terman had long believed that the academic community and the business community could and should work together for the benefit of both.(Note 34) Once Terman had attained a position of influence and power at Stanford, he practiced (and preached) a principle that he called ``steeples of excellence." Its cardinal rule was to go for the best. ``Academic prestige depends on high but narrow steeples of academic excellence; it is not possible to cover all the bases."(Note 35)

Terman, who died in 1982, never took credit for the development of Silicon Valley,(Note 36) but it is interesting to note in retrospect that a young man who fell ill at the age of 24, and who assumed that he would be unable to fulfill his destiny in the East, instead brought the world to his doorstep.

It has been said that an institution is the lengthened shadow of one man.

Inasmuch as Silicon Valley is an institution Fred Terman is that man the Father of Silicon Valley.

Notes

(1)William Hewlett, telephone interview, November 1984.
(2)Sandra Blakeslee, Stanford University News Service, 3 October 1977.
(3)Blakeslee.
(4)George F. Climo, Historian, Public Relations Services, Hewlett-Packard Company, telephone interview, February 1982.
(5)Blakeslee.
(6)Blakeslee.
(7)``Fred Terman’s favorite stories recalled by John Halamka, who lives in his basement," Campus Report, 12 January 1983.
(8)Blakeslee.
(9)Frederick W. Terman, telephone interview, November 1984.
(10)J. H. Morecroft, Principles of Radio Communication, Wiley, New York.
(11)F. E. Terman, Radio Engineering, McGraw-Hill, New York, 1932.
(12)Oswald (Mike) Villard, interview, Sunnyvale, California, 11 November 1984.
(13)Blakeslee.

(14)Blakeslee.
(15)Blakeslee; Villard; Hewlett.
(16)``Terman Dinner,'' concluding remarks, 5 May 1977 (provided by Professor Villard.)
(17)Dorothy Varian, The Inventor and the Pilot, 1983.
(18)Varian Associates Magazine, Volume 19, Number 1, January/February 1984
(19)Blakeslee; Villard.
(20)David Packard, ``Address honoring Dr. Terman,'' 31 May 1965.
(21)Gene Bylinsky, Fortune Magazine, ``California's Great Breeding Ground for Industry,'' June 1974.
(22)F. E. Terman, ``Address delivered at WEMA (Western Electronics Manufacturers Association) 30th Anniversary Dinner,'' 10 November 1973.
(23)Andrew Doty, Stanford University Office of Public Affairs, Stanford, California, telephone interview, November 1984. The original grant by the Stanford's plus accumulated land totaled 8,847 acres; since then 667 acres have been condemned for easements, leaving 8,180 acres.
(24)Bylinsky.
(25)John Linvill, interview Stanford University, Stanford, California, 26 July 1984.
(26)William B. Shockley, telephone interview, 24 May 1985.
(27)Bylinsky
(28)Linvill.
(29)Stanford Engineering News, School of Engineering, Stanford University, No. 92, January 1974.
(30)Don C. Hoefler, publisher of Microelectronics News, telephone interview, 9 January 1985. Hoefler was choosing a name for an article about the semiconductor industry that he was writing for Electronic News. Ralph Averts, then president of Ion Equipment, suggested Silicon Valley. Hoefler named his article, ``Silicon Valley USA;'' it was a series that ran for 3 weeks, beginning 11 January 1971.
(31)J. Parietti, American Electronics Association, telephone interview, 29 May 1985.
(32)Bylinsky.
(33)Bylinsky.
(34)Packard.
(35)Bob Beyers, Stanford University News Service, 19 December 1982.
(36)F. W. Terman.