

How the West Was Won

The Military and the Making of Silicon Valley

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The extraordinary story of Silicon Valley continues to intoxicate American business leaders, policymakers, and politicians alike. Despite its recent ups and downs, Silicon Valley remains a potent symbol of American high-technology competitiveness. In fact, no plan for regional economic development seems complete these days without its version of “silicon plain,” “silicon mountain,” or “silicon beach” (which at least makes some sense technically!).

Yet those who would emulate the example of Silicon Valley too often overlook a crucial part of the story. Behind the essentially self-serving image of the “new alchemists,”¹ “the big score,”² and “silicon valley fever,”³ behind the triumphant tales of freewheeling entrepreneurs and visionary venture capitalists lies a more unsettling reality about the military’s role, unintentional and otherwise, in setting America’s past industrial policy, and about the implications of that policy for our future industrial competitiveness.⁴

For better and for worse, Silicon Valley owes its present configuration largely to patterns of federal spending, corporate strategy, industry–university relationships, and technological innovation shaped by the assumptions and priorities of cold war defense policy. Indeed, the name Silicon Valley itself may be something of a misnomer, ignoring as it does the crucial role of microwave electronics and aerospace in providing this archetype for American high-technology industry. Created and sustained in the name of national security, Silicon Valley may offer limited guidance at best for an industrial policy aimed at a very different kind of international competition.⁵

Before World War II

For all its isolation from the centers of East Coast industry, the Santa Clara Valley played a surprisingly significant role in the early days of radio and electronics. Broadcasting pioneer Federal Telegraph (later bought by ITT) got its start in Palo Alto under Stanford graduate Cyril Elwell, with financial backing from Stanford's president and several faculty members.⁶ Audion inventor Lee de Forest worked there for a time developing more powerful arc transmitters, and in the process made the crucial observation that an audion could generate continuous waves.⁷ Charles Litton, another Stanford graduate, joined Federal's vacuum tube department following a stint at Bell Laboratories, then quit to go into business for himself when Federal moved the laboratory back east in 1932. William Eitel and Jack McCullough similarly left Heintz and Kaufman (cofounded by yet another Stanford graduate, Ralph Heintz) in 1934 to design and build their own tubes for the amateur radio market.⁸

Under Frederick Terman, Stanford University became the leading academic center for radio research on the West Coast. Son of an eminent Stanford psychologist, Terman grew up on campus, took his undergraduate degree there, and then headed off to M.I.T. for graduate training in electrical engineering. He returned to Stanford in 1925 with his doctorate and promptly launched an aggressive, commercially oriented program in radio electronics.⁹ Following M.I.T.'s example, he drew his research problems directly from industry and encouraged active collaboration between his students and local electronics companies. Terman did what he could to encourage young radio engineers to stay in the area. He arranged a special fellowship to lure one of his most promising graduate students, David Packard, back from General Electric, and put him to work with another top prospect, William Hewlett. Terman then helped his two students go into business in 1939 making audio oscillators based on ideas the three of them had been exploring in the laboratory. Walt Disney Studios bought the first batch for the *Fantasia* sound track.

Stanford also played a key role in fostering the klystron, perhaps the most important electronics innovation developed on the West Coast before World War II. In 1937 the Varian brothers, working with several Stanford physicists, invented the klystron, an original and extremely flexible microwave receiver and transmitter. Under an unusual contract with the university, the Varians were granted access to faculty, laboratory space, and modest funding for materials in return for a half interest in any resulting patents.¹⁰ A subsequent agreement between the university and Sperry Gyroscope Company provided substantial corporate funding for klystron research and development at Stanford and gave Sperry an exclusive license to make, use, and sell any microwave equipment developed in the university laboratory.¹¹ To follow up on its investment, Sperry set up a small development and production facility in nearby San Carlos.¹²

The War Years

None of the West Coast companies grew very large before World War II. To survive in an industry still dominated by eastern laboratories and patents, they had to exploit

technical niches, either by creating new products, like Hewlett-Packard, or by improving the performance and reliability of traditional ones, like Eitel-McCullough.¹³

Wartime orders gave the infant industry a chance to show what it could do. RCA, GE, Westinghouse, and the other East Coast giants won the lion's share of the defense electronics contracts, but even relatively small orders could make a big difference for the West Coast start-ups. Hewlett-Packard, spurred by massive orders for its line of electronic measuring instruments, jumped from nine employees and \$37,000 in sales in 1940,¹⁴ to one hundred employees and \$1 million in sales just three years later.¹⁵ Eitel-McCullough, on the strength of huge subcontracts from Western Electric and GE, grew even faster, churning out 100,000 tubes a week at the peak of wartime production.¹⁶ At the same time, it proved that it could still beat the competition in quality as well as quantity, mass-producing tubes that more established firms like GE could never seem to get right even as prototypes.¹⁷ Sperry, recognizing the dangers of too widely separating its research and development (R&D) from production, moved the entire Stanford klystron group out to its Long Island laboratories for the duration.

Terman spent the war directing the Radio Research Laboratory (RRL), a spinoff of the famous Radiation Laboratory housed upriver at Harvard and devoted to radar countermeasures. He brought along a number of Stanford students and colleagues—30 in all served tours of duty at RRL—and together they received a practical education in the art of microwave engineering. Writing to a colleague back at Stanford, Terman said:

I have learned a tremendous amount, for I had never before realized the amount of work required to make a device ready for manufacture after one had a good working model, such as the number of drawings, the amount of detailed design that is involved to turn out a good job, the problems of how to get stuff to meet specifications, testing and standardization problems, etc.¹⁸

Post-War Growth in West Coast Industry

Terman returned to Stanford in 1946 with a new title, Dean of Engineering, and a new vision of western industrial leadership:

The west has long dreamed of an indigenous industry of sufficient magnitude to balance its agricultural resources. The war advanced these hopes and brought to the west the beginnings of a great new era of industrialization. A strong and independent industry must, however, develop its own intellectual resources of science and technology, for industrial activity that depends on imported brains and second-hand ideas cannot hope to be more than a vassal that pays tribute to its overlords, and is permanently condemned to an inferior competitive position.¹⁹

Yet Terman and his colleagues recognized that the war had advanced more than hopes. By introducing new kinds of tubes and by opening up an entirely new range of the electromagnetic spectrum, it had revolutionized electronics. And since most of

that new knowledge had been created under government sponsorship, and would therefore be available to anyone, the East Coast industry would no longer be able to control the field through patents as it had done before the war. More than ever, they all realized, in the postwar world the secret of success was going to be research.

Terman and the core of electronics veterans he brought back with him from RRL and other wartime laboratories were especially well positioned by their wartime experiences to exploit the most recent advances in microwave electronics. Stanford's traveling-wave tube (TWT) program exemplified the new style of postwar electronics. Perfected at Bell Laboratories during the war by a team that included recent Stanford graduate Lester Field, the TWT offered significant improvements in bandwidth and tuning over other microwave tubes, making it ideal for electronic countermeasures applications. Terman knew about Field's work, recognized its implications, and convinced Field to continue his research back at Stanford.²⁰ With strong military support, Field rapidly established himself as one of the best researchers in one of the most competitive specialties in postwar electronics. Although on a shoestring budget compared with industrial efforts at Bell and RCA, Field and his students, including such future industry leaders as Dean Watkins and Stanley Kaisel, kept pace with the giants, developing new kinds of TWTs, increasing their power, and reducing their noise levels.²¹

The Sperry klystron group also came back to the West Coast after the war, determined to go into business for themselves. Some, like Marvin Chodorow and Edward Ginzton, joined the university faculty. Others, including Russell Varian, took temporary jobs as research associates. In 1948 they founded Varian Associates to design and manufacture klystrons and other advanced microwave tubes. The company literally got its start at Stanford. Its first board meeting was held on campus, its board of directors included several faculty members, and its first successful product, a tiny reflex klystron for guided missiles, was designed by a faculty consultant.²²

The Korean War transformed Varian and other fledgling electronic enterprises into big business. The sudden demand for microwave tubes for radar, electronic countermeasures, and communications gave these companies the inside track in securing defense contracts, especially the invaluable research and development contracts that could position them for the lucrative production contracts ahead. California's share of prime military contracts doubled during the course of the war, from 13.2 percent to 26 percent. From 1951 to 1953 California received some \$13 billion in prime contracts, overtaking longtime defense contract leader New York State.²³ That windfall represented not so much savvy political maneuvering, as some New York congressmen charged, but rather the success of California aerospace and electronics companies in anticipating, and cultivating, the military market. Most of that money went to southern California aerospace contractors in Los Angeles and San Diego, but Santa Clara County companies won their share, and before the end of the decade would be pushing San Diego for second place.²⁴

"Varian's growth during the first decade or so was rapid, primarily military based, and tied in closely with the growth of the aerospace industry," the head of its tube division recalled.²⁵ Its product line expanded into a full range of klystrons, from low-power models for airborne radar and guided missiles through medium-power versions for mobile communications and radar jamming to very-high-power tubes for

radar transmitters, all but a tiny fraction destined for the defense industry. To expand its output, Varian arranged a sizable loan through the Defense Production Administration, plus an additional \$1.35 million from the air force for a new small tube manufacturing plant.²⁶ Meanwhile, Varian's sales climbed from \$200,000 in 1949 to \$1.5 million two years later to \$25 million by the end of the decade, with military tubes accounting for all but a small fraction. Employment soared from 325 in 1951 to 1300 by 1958.²⁷ Varian strengthened its ongoing ties to the university by signing on as the first tenant of the Stanford Industrial Park, negotiating a long-term lease on university-owned land just south of campus for its research laboratories and its expanding tube department.²⁸

Litton's growth paralleled Varian's. Litton did a good business before the war designing and building machinery for manufacturing power vacuum tubes, and, like other tube-related companies, grew dramatically during the early war years. Charles Litton himself spent the war back at Federal Telephone's New Jersey plant making radar tubes. Afterwards, he returned to California and reorganized Litton Industries into a power tube manufacturer with a reputation for delivering high-quality magnetrons at prices bigger companies lost money on.²⁹ He then sold the company in 1953 to an aggressive group of Hughes expatriates led by Charles "Tex" Thornton, who dramatically expanded the operation to meet the sudden demand for tubes in the national air defense program. In just three years the new managers tripled sales (to \$6.2 million) and backlog (to \$36 million), and quadrupled employment (to 2115).³⁰ Like Varian, Litton Industries aimed almost exclusively at the military market, with such products as pulse magnetrons and tunable klystrons for radar and tunable continuous-wave magnetrons for jamming and missile guidance systems.

Eimac, though more commercially diversified than either Varian or Litton, also rode the wave of defense appropriations. It supplied high-power klystrons for virtually every major air defense project—the Dew Line, White Alice, and Pole Vault—tubes for missile tracking, and a truly giant klystron, the X626 (with 1.25 million watts of peak power) for ballistic missile detection.³¹ On the strength of those contracts, the company grew to 2600 employees and \$29 million in sales by 1959.

Stanford's laboratories continued to spawn innovative start-up companies looking for opportunities to commercialize the latest microwave technologies being developed there. Huggins Laboratories got its start in 1948 when founder R. A. Huggins, a former research associate at the university, put the first traveling-wave tube on the market. With a boost from government R&D contracts, Huggins continued to expand, diversifying into backward-wave oscillators, low-noise TWTs, and electrostatic focused tubes, all based on research done at Stanford. By 1961 Huggins was doing \$3.5 million of business a year and among the leaders in the TWT field.³² Ray Stewart, after a peripatetic early career with Litton and Dalmo Victor, joined Lester Field's group in the late 1940s as a technician, building some of the earliest TWTs. Though essentially self-taught, Stewart decided to try his luck in the market, first with vacuum tube furnaces and vacuum pumps, and then in 1952 with the first commercial backward-wave oscillator.³³ William Ayer, a graduate student in Stanford's Radioscience Laboratory, cofounded Granger Associates (with former RRL and Stanford Research Institute [SRI] researcher John Granger) in 1956 to produce ionospheric sounders and military communications equipment based on designs

pioneered at the university. By 1962 Granger Associates was doing \$5 million a year in sales.³⁴ In the meantime, Ayer and another Granger engineer spun off Applied Technologies to concentrate on electronic countermeasures and long-range detecting and monitoring equipment.³⁵ Its 1961 sales topped \$1 million. Stanley Kaisel, yet another Field student, spent two years working on TWTs for RCA, returned to Stanford during the Korean War to run a tube laboratory on a classified countermeasures contract, then took a job with Litton. Convinced that he could make more long-lived and reliable TWTs than what was currently on the market, he and another Litton engineer broke away in 1959 to form Microwave Electronics Corporation (MEC). Initially specializing in low-power, low-noise TWTs for electronic countermeasures, MEC built up \$5 million-a-year business with 400 employees by the time it sold out to Teledyne in 1965. Like Granger and Applied Technologies, MEC relocated in the Stanford Industrial Park to cement its academic connections.³⁶

Watkins-Johnson was undoubtedly the most financially successful of the new Stanford spinoffs. A former student of Lester Field, Dean Watkins had gone on to Hughes, then essentially swapped places with his mentor in 1953. At Stanford, Watkins led the Stanford TWT research to national prominence over the next few years, especially for work on low-noise TWTs. In 1957 he and former Hughes engineer Richard Johnson cofounded Watkins-Johnson to develop and manufacture microwave tubes for surveillance, reconnaissance, countermeasures, and telemetry, all directly based on the TWT technology Watkins had been perfecting at Stanford. Watkins-Johnson secured its initial financing from the Kern County Land Company, a large real estate and oil holding company looking for profitable investment outlets.³⁷ Watkins-Johnson immediately started returning money on that investment, turning a profit its first year. Sales rose from \$500,000 in 1958 to \$4.6 million in 1961 to \$9.5 million in 1963 to \$16.8 million in 1966, with consistently strong earnings.³⁸ Watkins-Johnson later acquired both Stewart Engineering and Granger Associates. By the early 1960s a third of the nation's TWT business, and a substantial share of the klystron and magnetron business as well, was located in the Santa Clara Valley, most of it a stone's throw from Stanford.

Response from the East Coast Industrial Establishment

That kind of success naturally attracted the attention of established East Coast companies ready to cash in on the burgeoning military electronics market. By East Coast standards, the West Coast start-ups were still puny. Industry leaders GE and RCA posted 1956 sales of \$725 million each. Admiral, Sylvania, Philco, Zenith, Westinghouse, and a dozen other companies had sales of over \$100 million. But with half of all electronics sales going to the military that year—\$3 billion a year in all—and an increasing share of that going for high-technology equipment for missiles, avionics, and the like, even the most myopic component maker could read the writing on the wall.³⁹ On average, military electronics was about the same or slightly less profitable than commercial business, about 10 percent on sales. But as *Fortune* pointed out, military electronics nonetheless represented “a whale of a good business,” both because the defense market was generally steadier than its commercial counterpart and

because military R&D contracts offered an inexpensive entry into new fields and enticing prospects for commercial spin-off.

Sylvania, primarily a manufacturer of television and radio tubes, got its chance to break into the military market in 1953 when the Army Signal Corps offered it a contract to construct a new laboratory for missile countermeasures. The Signal Corps had been considering some kind of facility for "quick reaction capability" (QRC) in electronic warfare since 1949,⁴⁰ and, forced into action by the Korean emergency, offered Stanford a \$5 million contract in 1952 to develop "engineering test models" of guided missile countermeasures. (All of the missiles in the U.S. and Soviet inventories in those days used radio guidance.) Concerned that any new contract might overwhelm its already taxed resources, Stanford begged off.⁴¹ So the next year, following a formal competition, the Signal Corps awarded Sylvania a \$3 million initial contract for studying and designing prototype electronic countermeasures against surface-to-target missiles and proximity fuses, two-thirds of the money for R&D and the rest for quick reaction tasks. The army would equip the laboratory and fund the research, while Sylvania would provide the land and the building and recruit the staff. For the company, the contract represented a quick, and very inexpensive, entry into the military electronics business. For the army, the laboratory represented an important step toward parity with the air force and navy in the missile race.

Although Stanford would not manage the laboratory directly, it nonetheless played a significant role in determining the laboratory's eventual location and research priorities. Sylvania's central research laboratory was then in Bayside, Long Island, New York. The army, however, insisted on a site that would not present such an obvious target. Sylvania knew all about Stanford's expertise in electronic countermeasures. Moreover, the company already had a small tube plant in nearby Mountain View. So Sylvania built its new Electronics Defense Laboratory (EDL) there, close to prospective Stanford faculty consultants and newly graduated engineers. The Signal Corps similarly recognized the advantages of putting the laboratory within Stanford's orbit, where subcontracts for search receivers, converters, special tubes, and other electronic warfare equipment developed by university researchers could more easily be arranged.⁴²

Over its first decade, EDL grew into one of the largest electronics enterprises in the valley, with some 1300 employees (including more than 500 scientists and engineers) and annual contracts of \$18 million.⁴³ (It currently has 3500 employees.) From a "captive" Signal Corps laboratory dedicated to missile countermeasures, EDL branched out into tactical countermeasures (against surface-to-air missiles and artillery fuses), and into electronic intelligence (intercepting and interpreting missile telemetry and guidance signals) for all the defense agencies.⁴⁴ By 1964 electronic intelligence accounted for two-thirds of the laboratory's revenues. EDL also earned a reputation for its QRC work, notably the spread-spectrum communications gear built, on a month's notice, for the Berlin crisis.⁴⁵

As anticipated, EDL drew extensively on its Stanford connections. It recruited heavily among both research associates and recent graduates. It hired several top faculty members as consultants, including Terman himself. And it became the first participant in the honors cooperative program, Stanford's pioneering effort to encourage more formal collaboration between high-technology enterprise and the university.

Local companies, starting with EDL and Hewlett-Packard, sent their best young engineers back to school part-time for advanced degrees. EDL got better-trained people, plus a direct pipeline to Stanford ideas. By the early 1960s EDL was sending 92 people a year to the program.

Along the way, EDL spun off several laboratories devoted to specific technologies. In 1956 Sylvania set up an independent Microwave Physics Laboratory for advanced research on ferrites and plasma.⁴⁶ The next year it established the Reconnaissance Systems Laboratories, specializing in satellite detection and other air force priorities, first in a converted supermarket in downtown Mountain View and later in its own facilities next to EDL.⁴⁷ Four EDL engineers broke away in 1956 to form Microwave Engineering Laboratories, initially concentrating on solid-state microwave devices for the military market.⁴⁸ And in 1964 EDL director William Perry, frustrated with what he considered home office exploitation of the laboratory, defected, along with a half dozen senior managers, to found Electronic Systems Laboratories (ESL, Inc.) as a direct competitor in electronic intelligence.

General Electric moved west in 1954 looking for ways to enlarge its already considerable share of the defense electronics business by tapping Stanford expertise. GE's Electronics Division had recently established an advanced radar laboratory in Ithaca, New York (on Cornell University land) to assist its heavy military electronics group in Syracuse. At Stanford, it saw a similar opportunity to cash in on academic research in high-power klystrons, TWTs, and other exotic hardware.⁴⁹ In 1954 it opened what it called the General Electric Microwave Laboratory at Stanford in the Industrial Park. Like Sylvania, GE hired a number of recent graduates and research associates outright, including coupled-cavity TWT pioneer Erwin Nalos (a former Chodorow student), signed up several faculty consultants, and sent dozens of its most promising engineers to the honors cooperative program.⁵⁰ Sixteen of its forty top scientists and engineers had been at one time either graduate students or faculty members at Stanford.⁵¹

At first the laboratory concentrated almost entirely on elaborating concepts originally developed at the university. Gradually, however, it established its own reputation as a center for work on high-power klystrons and TWTs (for radar systems) and on low-noise TWTs, including the first metal ceramic designs (for electronic countermeasures systems). By 1956 it was bringing in two-thirds of its annual research budget in independent military contracts.⁵² It supplied the TWTs for GE's Rainbow, the first frequency diversity radar, the klystrons for the Nike-Hercules radar, the mammoth klystrons for Westinghouse's missile defense system, and the small low-noise TWTs for Sylvania's countermeasures systems.⁵³ The laboratory doubled in size after its first two years, doubled again a few years later, and then doubled once more, to 336 employees and a \$5 million annual budget, by 1958.⁵⁴

Following Sylvania and GE's lead, other East Coast companies established outposts in the area. Sensing the shift in the market, Chicago-based television and radio giant Admiral, which had been supporting a small color television laboratory in Palo Alto since 1952, opened a new laboratory in the Stanford Industrial Park in 1955 for research on radar, guided missiles, and air navigation and communication systems.⁵⁵ It later won large air force and navy contracts for designing and manufacturing auto-

matic decoders for identification, friend or foe (IFF) systems.⁵⁶ In 1956 Zenith set up a research laboratory nearby, under one of Terman's former group leaders at RRL.⁵⁷

Lockheed Missiles and Space came to the valley in 1956 looking to break into the missiles and space market by breaking out of a corporate culture dominated by airplane enthusiasts. It opened a major manufacturing facility in Sunnyvale and a complementary laboratory complex in the Industrial Park. Significantly, in selecting the Stanford location Lockheed's president stressed the university's reputation in electronics rather than aeronautics. With the increasing complexity and sophistication of guidance and communications systems, Lockheed felt it could no longer rely on outside electronics expertise and would have to develop its own. "To handle these big defense systems involving billions not millions of dollars and covering a multitude of sciences, we must broaden and deepen our competence into fields related to ours," Lockheed's president stressed. "The one I think of as most logical and natural is electronics."⁵⁸

Lockheed's investment paid off immediately and spectacularly. Lockheed Missiles and Space won the Polaris submarine missile contract (initially worth \$62 million), from the navy, and the first reconnaissance and surveillance satellite contracts from the CIA and the air force.⁵⁹ On the strength of those projects, Lockheed's employment soared from 200 in 1956 to 9000 in 1958 to 25,000 in 1964 (with 1200 in the research laboratories alone), making Lockheed, by an order of magnitude, the biggest employer in the valley.

Lockheed provided a crucial catalyst for further high-technology growth. Lured by the prospects of lucrative subcontracts for the ground support and tracking network for the air force satellite programs, Philco broke ground for its multimillion-dollar Western Development Laboratories (WDL) in Palo Alto in 1957. About 90 percent of its sales in the early years came from air force contracts for satellite tracking and command systems.⁶⁰ WDL later won a Signal Corps contract for Courier, the first active-repeater communications satellite, a \$31 million army contract for a worldwide teletype and high-speed digital data communications system, and a \$25 million contract for a Department of Defense (DOD) communications satellite network.⁶¹ These and other contracts pushed WDL employment to 2500 by 1960. Ford, frankly looking for a toehold in the defense and space business, bought Philco the next year and made WDL the core of its new aerospace division.⁶² Under Ford, WDL continued to be a major player in the satellite business, winning additional large contracts for communications satellites, antenna systems, and the NASA flight control center in Houston.

The aerospace industry offered opportunities for smaller companies as well. Four local scientists founded Vidya in 1959 to conduct supersonic wind tunnel tests on the Polaris nose cones. Itek, the Massachusetts-based antenna manufacturer, bought out Applied Technology to give it a West Coast presence. Link Aviation, the Binghamton-based flight simulator manufacturer, shifted its advanced engineering laboratory to Palo Alto in 1957, adding a line of simulators for guided missiles. Kaiser Aerospace relocated to the Industrial Park a few years later. Even local tape maker Ampex found a booming new market for its recording systems in reconnaissance satellites and guided missiles.

When Fairchild Semiconductor was still just Robert Noyce and two dozen bright young engineers, the Undersecretary of Commerce was calling Santa Clara County the “microwave capital” of the world.⁶³ Indeed, by 1960 it had already become the center of an aerospace complex rooted in microwave electronics technology for reconnaissance, communications, and countermeasures, with its main trunk at Lockheed Missiles and Space and the adjoining Air Force Satellite Control Facility (or the Blue Cube)⁶⁴ and its branches extending in all directions. Electronics Defense Laboratory director William Perry caught something of how the corporate components of this complex intertwined:

We are continually demanding microwave tube performance beyond the state of the art. We were one of the companies pushing that industry to get more and more bandwidth, more and more power, more and more ease of tuning. So there were an amazing set of technical developments going on in tubes at that time and they were being driven by electronic countermeasures companies.⁶⁵

Similarly, Watkins-Johnson bought low-noise tubes from GE’s microwave laboratory, reverse-engineered them, and then brought out its own. Those tubes and others like them went into the systems Sylvania was building for Lockheed’s satellites, and into the communications and tracking gear being designed by Philco’s Western Development Laboratories. Microwave tubes provided the “linchpins” for virtually every contemporary military electronics system, from radar to electronic warfare. And not just anyone could build them. The biggest cost upwards of \$200,000 each, and took such skill to manufacture properly that insiders liked to say that to get one right “you pray over it, you nurse it, you make love to it.”⁶⁶

Hard Times in the Valley

The aerospace complex prospered in the post-Sputnik defense boom, but at the cost of increased isolation from the commercial world outside. GE’s Microwave Laboratory never really found a place for itself in the larger corporation. Other divisions, lacking experience in the microwave tube art, could never satisfactorily duplicate TWTs and other tubes based on the laboratory’s designs. From the perspective of GE’s power tube division, the laboratory’s corporate parent, high-power microwave tubes offered limited commercial possibilities. So rather than using the laboratory to break into new high-technology markets, upper management turned it instead to “putting out fires for other manufacturing divisions.”⁶⁷ Dissatisfied with that role, many of the best engineers left for more promising opportunities elsewhere, some of them right next door. By 1965 the GE Microwave Laboratory staff was down to 170, less than half its peak strength.

Sylvania similarly failed to capitalize on EDL. Although the division itself remained profitable, it developed only the most tenuous connections with the rest of the corporation. GTE bought out Sylvania in 1960, in part to acquire a central laboratory for its telephone business. Despite some attempts to spin off commercial technologies, including electronic security systems, testing devices for telephone

headsets, industrial lasers, and even a Sociosystems Products division, GTE Government Systems (as it was renamed) remained too specialized and too expensive to compete in the civilian world. “The government doesn’t train us to do things cheaply,” one senior scientist explained.⁶⁸ While continuing to do 90 percent or more of its business with the military,⁶⁹ GTE also tried to set up a separate commercial laboratory in Palo Alto, a “miniature Bell Telephone Laboratories for serving the GT & E system, and financed at least in part from telephone revenues,”⁷⁰ and, surprisingly enough, hired the recently retired Chief Signal Officer to organize and run it. GTE’s operating divisions, convinced that such an enterprise was unlikely to contribute much to their mission, immediately backed out, and put their money into the old Bayside laboratories instead.

One by one, the transplants to the valley shut down or sold out. Admiral closed its Palo Alto laboratory in 1964 and sent the 100 remaining researchers back to Chicago,⁷¹ as did Zenith. Sylvania sold off its TWT division to Microwave Electronics and its ferrite components division to MELabs to concentrate on its core defense business. Varian, looking to make up lost ground in the TWT market, bought up what was left of the GE Microwave Laboratory in 1966 and merged it with its tube division.⁷²

With the conspicuous exception of Hewlett-Packard, which had always concentrated on commercial technologies, the remaining microwave electronics companies never really cracked the civilian market. Varian diversified into analytical instruments and medical electronics, as did a few of its local competitors, but none of them managed to break their essential dependence on defense contracts, or on the culture of classified projects and security clearances that sustained those contracts. Like Lockheed itself, which virtually abandoned the civilian market altogether, they staked their futures on the procurement policies of the national security establishment.

Nor did the microwave electronics companies make the transition to the semiconductor business—again with the conspicuous exception of Hewlett-Packard—although their experiences served as the prototype for the integration of academic, corporate, and military R&D behind Silicon Valley’s later takeoff. Some of these companies served as important customers for the emerging semiconductor industry, mostly for specialized military devices; others, recognizing the growing importance of solid-state devices for their own businesses, built up semiconductor expertise in-house. Most lost at least some of their best engineers to the semiconductor start-ups, since in those days no one knew more about electron physics than the tube specialists. But none of them cashed in on the chip bonanza that gave Silicon Valley its name and reputation.

The Silicon Valley Model?

Back in 1965, as Silicon Valley was just beginning to take off, Bell Laboratories president James Fisk cautioned against placing too much confidence on this model of industrial competitiveness. Thanks to “intense federal subsidy of electronics, space vehicle and guidance operations, communications and computer programs,” places

like Silicon Valley and Route 128 (Massachusetts) appeared to be seedbeds of innovation. But the innovations spawned there, however important for the national defense, would not necessarily translate into “the sort of enduring, economically productive high employment industries which are the backbone of this nation,” he warned. “We believe it would be inaccurate and probably eventually dangerous to persist in the presumption that this is the way to start and maintain important industrial innovation.”⁷³ What America really needed to compete were policies aimed at strengthening and revitalizing older industries as well as creating new ones. And that could not be done by following a model of industrial development that “depends so heavily on federal subsidy as do these classic spinoffs from the universities.”

In the short run, Fisk was wrong. If few of the original electronics companies in the valley succeeded in breaking their dependence on federal subsidy, second- and third-generation companies often did, sometimes in spectacular fashion. But even they could not seem to master the “missing consumer connection” dividing the high-tech world of Silicon Valley from the larger world of consumer electronics,⁷⁴ no doubt in part because that connection had never been an integral part of Silicon Valley. Consequently, as Fish had foreseen, Silicon Valley could not by itself revitalize America’s basic industries, or restore American competitiveness.

Notes

1. Dirk Hansen, *The New Alchemists: Silicon Valley and the Microelectronics Revolution* (Boston: Little, Brown, 1982).
2. Michael Malone, *The Big Score: The Billion Dollar Story of Silicon Valley* (New York: Doubleday, 1985).
3. Everett Rogers and Judith Larsen, *Silicon Valley Fever: Growth and High Technology Culture* (New York: Basic Books, 1982).
4. A. Markusen, P. Hall, S. Campbell, and S. Deitrick, *The Rise of the Gumbelt: The Military Remapping of Industrial America* (New York: Oxford University Press, 1991) makes a strong case for seeing cold war industrial policy as a deliberate strategy of the Pentagon and its corporate contractors. While I am not convinced of the intentions, I am convinced of the implications they describe.
5. Richard Florida and Martin Kenney, *The Breakthrough Illusion: Corporate America’s Failure to Move from Innovation to Mass Production* (New York: Basic Books, 1990) challenge the appropriateness of the Silicon Valley model on the grounds of its present difficulties in exploiting innovation, without attention to either the character or pattern of that innovation.
6. Arthur L. Norberg, “The origins of the electronics industry on the Pacific coast,” *Proc. IEEE*, Vol. 64, No. 9, September 1976, pp. 1314–1322, is the best account of the early West Coast radio industry.
7. See Hugh Aitken, *The Continuous Wave: Technology and American Radio, 1900–1932* (Princeton, N.J.: Princeton Univ. Press, 1985), pp. 233–246.
8. Norberg, *Proc. IEEE*, op. cit., pp. 1318–1319; ———, “Eitel-McCullough, Inc.,” *Micro-wave J.*, August 1960, pp. 85–90.
9. The best sketch of Terman’s early career is A. Michal McMahon, *The Making of a Profession: A Century of Electrical Engineering in America* (New York: IEEE Press, 1984), pp. 183–87.

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