THE ORIGINS OF SILICON VALLEY: WHY AND HOW IT GOT STARTED

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ABSTRACT
Silicon Valley – an area that encompasses San Francisco and its extended suburbs to the south, including San Jose – is commonly known as the tech capital of the world. When most people think of the Valley, they probably think of semiconductors, personal computers, software, biotech and self-driving cars. But it was a hub for innovation long before the rise of personal computing, or even the transistor.

Some consider the start of Hewlett-Packard Company as the beginning of what would become Silicon Valley; others date the start of the story to the founding of William Shockley's silicon transistor company, Shockley Semiconductor Laboratory, in Mountain View. But the seeds for what was to become Silicon Valley were actually sown 50 years earlier.

TEHCNOLOGY IN THE USA

The early tech hub in America was in the New York/New Jersey/Philadelphia area during the 19th century. It was here that Alexander Graham Bell developed the telegraph and telephone, the genesis of American Telephone and Telegraph, in NYC. In New Jersey, Edison developed power generation and distribution and the electric light bulb. Lee de Forest patented the first vacuum tube there, and both AT&T and RCA did early development in this technology. Innovations poured out of AT&T's Bell Labs, as well as RCA's Sarnoff Labs, both located in New Jersey.[1,2]

However, government policy and industrial practices that tried to keep the new tech localized were the eventual key forces that moved the center of innovation to the USA's West Coast. In this talk, you'll learn why this happened, the steps that it took, and how other regions of the world might benefit from this knowledge.

AGRICULTURAL BEGINNINGS

In the late 1800s, California's Santa Clara Valley, 80 kilometers south of San Francisco and anchored by San Jose, was known as the Valley of Heart's Delight. The region got this nickname because of its blossoming fruit trees and abundance of agriculture. The development of the refrigerated railroad car opened markets in the Midwest and East to fruit shipments from the Santa Clara Valley and vegetables from California's Central Valley. Shipments of its apricots, cherries, and prunes – along with the gold still being mined in the Sierra foothills – brought wealth to the region, as Leland Stanford had predicted (Figure 1). Steamships from the Hawaiian Islands and Asia headed for San Francisco's seaport. But San Francisco was relatively unknown compared with other U.S. cities such as Boston, Philadelphia, Chicago, and New York. Stanford University was a young school, founded on Leland Stanford's stock farm in 1891 in the sleepy town of Palo Alto.

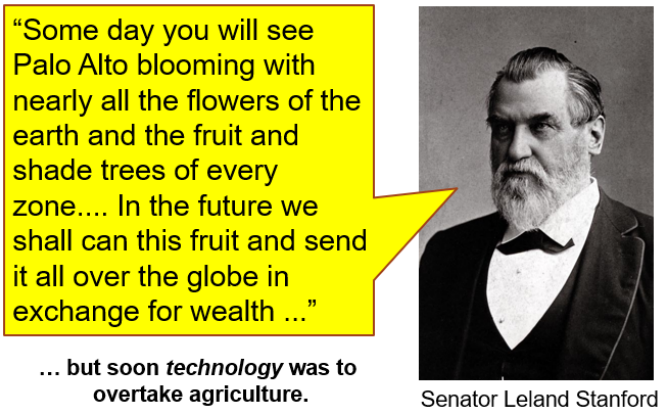

Figure 1. Late 1880's prediction

THE FIRST RADIO COMPANY

That began to change in the early 1900s. A young Stanford University engineering graduate, Cyril Elwell, sought a better design to replace the noisy spark radio transmitters of the day. He travelled to Denmark to obtain a North American license for the Poulsen arc transmitter (Figure 2), the first continuous-wave transmitter, as an improvement to the existing spark technology. Forming Federal Telegraph in 1909, he raised funds locally, including $500 each from Stanford's president, David Starr Jordan, and several university professors – the first use of "Angel funding". He set up operations in the Palo Alto home of his chief engineer, scaled up the design, and experimented with these continuous-wave methods. In 1909, another Stanford engineer, Charles "Doc" Herrold, started a radio arts school in San Jose, using an arc transmitter for his Wednesday-evening test transmissions to his nearby students – the first scheduled broadcasts in the USA; his wife Sybil, as the first disk jockey, would spin new-release music recordings. This eventually became S.F.'s radio station KCBS.[3]

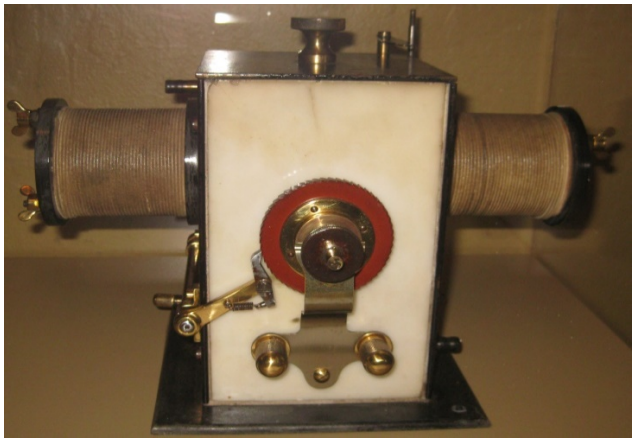

Figure 2. Poulsen arc transmitter, 1909

Lee de Forest holds the patent for the first vacuum tube, the Audion, which he developed in New York. He came to Palo Alto in 1911 for several years to work at Federal Telegraph and continued his experimenting with this device. Exploring new uses, he proceeded to patent the oscillator and amplifier circuits. Several improvements were made to his basic Audion (Figure 3). In 1915 he sold his patent rights to AT&T, with Federal Telegraph retaining shop rights to the patents.

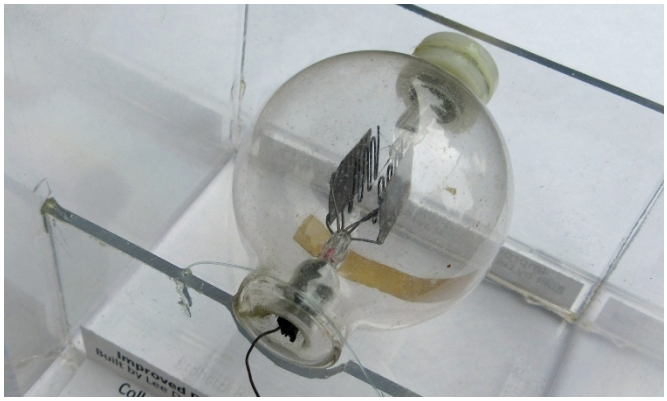

Figure 3. Improved Dual-Wing Grid Audion (ca 1912). Collection of Paul Wesling

Federal continued development, demonstrating reliable communication between San Francisco and Honolulu and then establishing a network of stations covering the steamship lines across the Pacific Ocean. Its business was charging for message exchange between ships at sea and their home companies. The US Navy found this technology quite useful for long-distance communication, engaging Federal to establish high-power stations in Alexandria, VA, the Canal Zone, Spain, the Philippines and other locations.

The sinking of the RMS *Titanic* in 1912 brought focus to radio as a potential life-saving technology. Although the radio operator on the ship sent out emergency messages that night, the operator on the nearby SS *Californian* had left his station and gone to bed. Later that year, U.S. federal laws were changed to require shipping companies to have operators monitor radio signals around the clock. The U.S. Navy liked the technology developed by Federal Telegraph for ship-to-ship and ship-to-shore communications and installed the radio system on its vessels.

AFTER WORLD WAR I

Realizing radio's potential, the US Navy wished to contain new developments to the USA. It arranged with the General Electric Company to form a new entity – Radio Corporation of America (RCA) – to centralize the technology and limit its spread to other parts of the world. AT&T and Westinghouse also contributed their intellectual property in the new field, amassing most of the foundational patents into the new entity. RCA then licensed radio and tube technology only to fully USA companies. Certain foreign companies, including the Marconi Company in the USA, were bought by American companies. Radio continued to show promise for reliable long-distance communication, such as replacing undersea cables and trans-continental links.

Federal Telegraph and several other SF Bay Area companies were manufacturing radio equipment for foreign customers, including for International Telephone and Telegraph (ITT), so they were prohibited from making equipment using RCA's patented circuits and devices. This created a quandary: could they stay in business and make improved equipment? The only way open was to disrupt the RCA monopoly with new and better technology – a hallmark of what became Silicon Valley.

GOING HEAD-TO-HEAD WITH RCA'S LICENSEES

Much early development in radio was pioneered by amateurs – what are called Ham Radio operators – rather than by companies. These individuals gathered loosely in small groups or clubs, where they shared ideas and helped newcomers get started. They are gathered under the umbrella of the American Radio Relay League (ARRL). One such group of teenagers developed on Stanford's campus among the children of faculty – Fred Terman, Roland Marx, George Branner, Jack Franklin, and Herbert Hoover Jr. Aged from 12 to 15, they experimented with radio contraptions during their high school years (Figure 4). Fred Terman would spend time around Federal's production facility, a few miles south of the campus, obtaining advice and getting parts; one summer, during college, he worked at Federal. The same path was open to other youngsters and adults, where individuals built their reputations through innovation or clever circuits and antennas, first competitively mastering some new technique, and then collaboratively sharing it with others in their group, and more broadly. This was the ham radio culture that continued with the Homebrew Computer Club and other instantiations of friends and hobbyists gathering together to made advancements.

Figure 4. Fred Terman at 17, with his ham radio

Several of these young hams played a particularly important role in helping the SF Bay Area's infant industrial companies compete with the RCA licensees: William Eitel, Jack McCullough and Charles Litton.[4] They were introduced to ham radio by families and friends. They were joined a decade or two later by Russell and Sigurd Varian and William Shockley. Born and raised in the Santa Clara Valley, and active in radio technology, they represent the experimenters and inventors who propelled Valley companies into the forefront of technology worldwide.

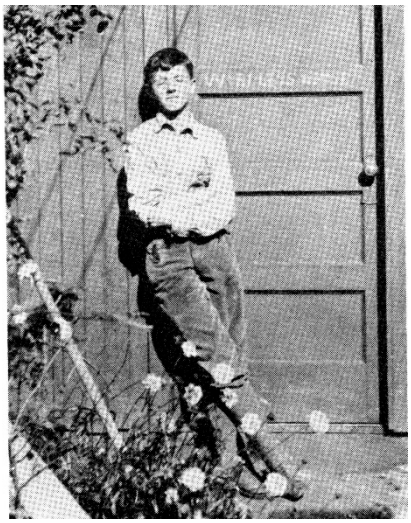

Figure 5. Charlie Litton at 11, outside his "Wireless House"

At the age of 11, young Litton already had a "Wireless House" – a small shed where he played with the new technology (Figure 5). Bill Eitel's father had a quarry in the Santa Cruz Mountains where, as a high school kid, he was a machine operator and did repairs; he also worked summers at his uncle's engine factory in nearby Oakland. Litton and McCullough attended a hands-on high school in SF – the California School of Mechanical Arts – where a free education was offered for boys and girls interested in the mechanical trades. Litton said he gained "a realistic 'feel' of materials and processes" there during his high school years. These ham friends experimented with vacuum tubes and built their own equipment. After his degree from Stanford, Litton joined Federal to head up its tube-design shop. Eitel joined Heinz and Kaufman, a designer of radio sets, in a similar position, and McCullough was hired at H&K a year later based on his ham radio background. The challenge: to design around RCA patents and develop new materials and processes for vacuum tubes, since these companies could not purchase transmitting tubes from RCA's licensees. This was successful, in part because these ham friends continued to work collaboratively to solve problems. Litton developed new processes and methods, notably design of the glass lathe, for much improved precision, repeatability and speed in fabricating the tubes.

THE DEPRESSION IN THE 1930'S

As Federal was purchased by an East Coast company and H&K lost profitability and business during the worldwide depression, Eitel and McCullough left to form their own company, receiving financing from several Bay Area businessmen; this was likely the first "venture capital", with the investors getting 50% of the company and the entrepreneurs owning the other half. Both investors made large profits on their $20,000 investments, and the company, Eitel-McCullough (known as Eimac) focused on better tubes for the ham radio market (Figure 6). As the new startup got underway, Litton gave Eimac the blueprints for the glass lathe and his oil vacuum pump. There was a free interchange of information, so necessary for small, struggling companies, but something that wouldn't have been seen in more vertically integrated companies typical of the Northeast USA.

Figure 6. Eimac ham radio tube advertised in the ARRL's *QST* Magazine

Figure 7. Eimac 50T

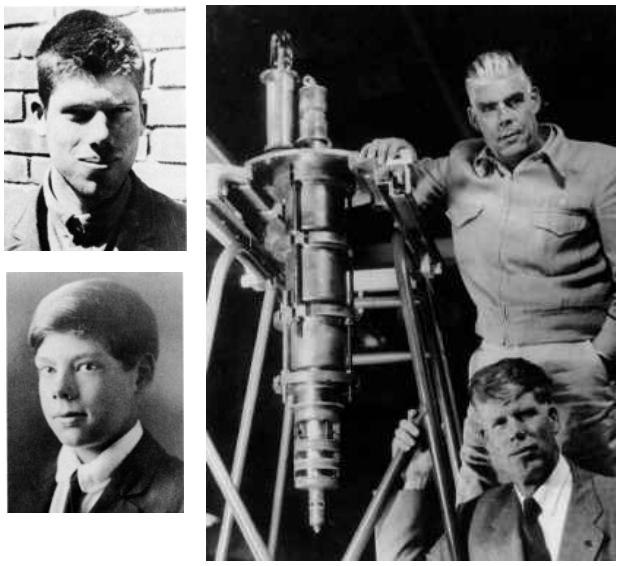

Figure 8. Sigurd and Russell Varian as boys in Palo Alto; with an early Klystron

Fred Terman, now heading up the Stanford electrical engineering department, hired Litton part-time as a lecturer and to guide students and staff in the labs. When Sperry designated $1,000 for some Litton intellectual property, he made this available to Terman. Terman wrote to a 1934 graduate – David Packard – who was working for G.E. on the east coast, inviting him to use the funds as support so that he and Lucile could return to Stanford for graduate work, where he was introduced to another grad student, Bill Hewlett.[5] The two engineers developed a circuit invented by Hewlett to design an audio oscillator; Terman assisted the two in starting their own company, Hewlett Packard Co. This example of university-startup cooperation echoed what Jordan and Elwell had pioneered three decades earlier, and was rather unique to the Santa Clara Valley.

During the late-30s, as the system of radio detection and ranging (RADAR), developed initially in England, was under development by the US Navy, only the Eimac high-voltage high-frequency tubes were best adapted to the task (Figure 7). Russ and Sig Varian were two boys who grew up in Palo Alto (Figure 8); they worried about the rise of German capabilities, and wondered if microwave frequencies could be used to significantly improve RADAR. Russ moved into Bill Hansen's physics lab, and jointly (with Litton's help) developed the klystron, a key contribution to both RADAR and electronic detection and countermeasures.[6]

During World War II, Terman led the Radio Research Laboratory at Harvard, but as the war ended, he and many others came back to the Stanford campus. By this time, Stanford and the SF Bay Area were leaders in microwave development. Industrial practices during the war led to employee benefits such as profit-sharing, tuition reimbursement, medical clinics (the start of the Kaiser Permanente health system) and other enlightened management techniques. The "H-P Way" of defining company/employee/customer partnering spread across the Valley.[7]

RCA wasn't able to produce tube designs that worked at VHF frequencies, so they infringed some of Eimac's patents; in 1947, Eimac sued RCA and G.E., winning a patent-infringement judgment that halted their production. The technologists in what was to become Silicon Valley had again proved disruptive, and these critical tubes were now mostly produced here. They led to UHF TV and FM radio, as well as the linear accelerator (klystrons are in use today for radiation treatment of cancer).

THE 1950's

Bill Shockley, who grew up in Palo Alto (Figure 9) and whose mother still lived here, was co-inventor of the transistor while at Bell Labs; with funding from Arnold Beckman, he started his silicon transistor company in nearby Mountain View. Gathering key physicists, chemists and engineers from across the country (including Bob Noyce, from Philco in Philadelphia),[8] he improved several types of silicon devices. Two years later, Fairchild Semiconductor was started by 8 of these entrepreneurs, using venture capital, and taking advantage of the high-vacuum technology, glass-blowing expertise, quartz machining, and other developed Valley processes to start producing transistors and then integrated circuits. A key development was the planar process, which underlies all IC production today. As entrepreneurs started dozens of other semiconductor and equipment companies over the next decade, the sharing and collaboration exhibited earlier continued among the engineers at these small startups. With cold-war defense funding providing a much-needed market, these companies thrived and continued the fast-paced development of new technologies.

Figure 9. Bill Shockley, at 8, at his Palo Alto home

A good example of this "Valley culture" of sharing among hobbyists and inventors was the Homebrew Computer Club, started in Menlo Park, adjacent to Palo Alto. Steve Wozniak used the newly released, inexpensive 6502 microprocessor to develop a single-board computer, the Apple I, and – with a neighbor of his, Steve Jobs (Figure 10) – showed it off at one of the Club meetings. Woz merely wanted to help others duplicate the design and improve on it, in the spirit of collaboration characteristic of the ham radio culture, but Jobs

felt there was a business opportunity there. This partnership developed into the largest brand in the world. Labeled Silicon Valley in 1971, the SF Bay Area now attracts about half of the venture capital in the USA, with no other region exceeding 10%.

Figure 10. Wozniak and Jobs, introduced to each other by a neighborhood friend Bill Fernandez. The density of nerds in Silicon Valley is high.

A more recent example is Sun Microsystems, the first designer of powerful workstations. The founders were a pair of Stanford MBA graduates (after degrees from Harvard and Carnegie Mellon), two UC-Berkeley grads (one with a degree from University of Michigan), and another a Stanford PhD (from Carnegie Mellon). It's first backer was John Doerr of Kleiner Perkins, the venture capital firm. Drawn to the Silicon Valley dynamic, they covered hardware, software, and networking. And yet, fortunes can change – today, the front of the corporate sign shows the Facebook thumbs-up signal, while the back (only visible by walking behind it) is the old sign for Sun Microsystems. Silicon Valley is a very dynamic place.

This study covers the days of radio and analog electronics in the SF Bay Area. However, the local leadership in innovation has been maintained through newer technologies: digital, software, the mouse and graphical user interface, biotech, mobile computing, Big Data, Deep Learning, virtual and augmented reality, and now autonomous vehicles. Its growing companies invest in leading-edge ideas – and thanks to California's 1870s law that doesn't allow enforcement of non-compete clauses in employment contracts, any team of employees can leave an existing company and easily start a new one with their friends, with no one- or two-year waiting period. The universities produce an environment for innovation and startups; by the 1990s, Stanford was turning out 800 masters and PhD grads each year to feed into local enterprises.[9] In earlier days, these included Vint Cerf (the TCP/IP protocol), Ted Hoff (the first microprocessor), and Sandra Learner (Cisco and networking); graduates of MIT, Harvard and other schools tend to migrate west for the dynamic environment. There are a number of incubators generating hundreds of new startups each year. And the combination of competition and collaboration evidenced by the ham radio culture and the Homebrew Computer Club lives on in MeetUps and open-source projects that generate additional partnerships and small companies with the chance to become tomorrow's Unicorns and leading corporations.

TODAY'S SILICON VALLEY CULTURE

A summary of advantages offered by the Silicon Valley environment might include:

- Competition ***and*** cooperation
- Small, specialized firms (not vertically integrated)
- Often hobby-focused (for start-ups)
- Fluidity and flexibility (ability to "pivot")
- Egalitarian (in parking, offices, "open door" policy, 10% time, Friday beer busts, employee focus)
- Favorable California legal framework (no enforcement of non-compete clauses)
- A great university willing to engage with startups (university-industry relations)
- Large pools of entrepreneurs, technologists and opportunities (attracting additional techies)
- Energetic entrepreneurs from previous companies (both successful and failed) available to staff the next enterprise
- Ready venture capital (Sand Hill Road in Menlo Park)
- Failure is a *feature*, not a bug

Many of these attributes can be found, to greater or lesser extent, in other technology hubs; however, the SF Bay Area has several generations of experience with most of them, making it difficult for others to catch up. If problems such as the cost of housing, traffic congestion, and infrastructure can be mitigated, Silicon Valley stands a good chance of remaining the hub of technology development moving forward, where geeks bring tomorrow's ideas to life. After all, the best way to predict the future is to invent it.

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