Spencer Tang

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History 177R

Graves

Fairchild Semiconductor’s Early History and Contributions to the Modern Semiconductor Industry

The organization, business strategies, and technological advancements carried out by Fairchild Semiconductor from 1957 to 1961 has left a lasting mark on Silicon Valley’s contemporary paradigms. In this short span of time, the company carved out a significant business niche for itself, outdoing competitors by focused development and the introduction of key technologies, such as the planar process and silicon integrated circuits. This paper will discuss the circumstances which allowed Fairchild Semiconductor to be founded and how it went about shaping an infant semiconductor industry.

Silicon Valley before the introduction of its semiconductor and hardware manufacturing sector was already a location on the forefront of technology. High technology in the early 20th century revolved around the early amateur radio industry. The San Francisco Bay area during the “mid 1910s and the early 1920s” contained “more than 1,200 licensed amateurs, about 10 percent of all the radio operators in the United States.”[[1]](#endnote-1) Major cities such as Oakland and San Francisco had radio clubs which congregated large numbers of hobbyists from diverse occupations and economic backgrounds. Factors which made California especially suitable for this early radio scene included its large seaport and heavy presence of both commercial shipping and the U.S. Navy. Both industries heavily leveraged radio communications for their own economic and military purposes. This also provided a major source of employment for radio operators.[[2]](#endnote-2) In many ways, the spirit and culture of this amateur radio scene influenced Silicon Valley’s would-be entrepreneurs and early engineers.

Amateur radio enthusiasts at club meetings and hamfests emphasized democratic, egalitarian values and lauded technical expertise and resourcefulness. They valued healthy, productive inter-competition in the pursuit of more efficient circuits and better transmitters.[[3]](#endnote-3) These friendly competitions between radio enthusiasts were analogous to Fairchild Semiconductor’s fierce competition with their rivals in transistors and miniaturized circuits. Various vacuum tube companies sprouted up to meet the radio technology demands of both industry and the U.S. military.

Firms such as Eitel-McCullough, Litton Industries, and Watkins-Johnson provided a model for West Coast manufacturing companies to compete with their larger East Coast rivals.[[4]](#endnote-4) The path forward involved “innovative manufacturing” and “high-quality products.” These companies found their business niches by exploiting specific, disruptive products. Semiconductor companies leveraged ceramic, glass, and skilled machinery shops which used to supply vacuum tube companies. Some vacuum tube specialists, especially the process engineers with knowledge of fabrication, “chemical handling, glass working” and “vacuum techniques” moved to semiconductor firms in the 1960s.[[5]](#endnote-5) Fairchild Semiconductor consulted with Varian and other vacuum tube companies for strategic and management advice in their early years. Meanwhile, large geopolitical forces of the post-World War II order were actively reshaping the nation’s political and military institutions.

The 1950s was a period of increasingly high political tensions between both the United States and the Soviet Union: a period best described as the Cold War. The Korean War, which began in 1950, ended in stalemate in 1953. As a rough equivalent of NATO, an alliance tying the nation to the military defense of Western Europe, the Soviet Union created the Warsaw Pact in 1955. [[6]](#endnote-6) Americans were caught offguard when the Soviets in October 1957 launched Sputnik, setting the stage for the Space Race. As technological knowledge and expertise began to carry even greater strategic importance, the American military began to invest heavily into its intercontinental ballistic missile program. Prior to1956, when the military pushed for “digitalization of its avionics equipment,” most of its aircraft and missiles relied on analog systems.[[7]](#endnote-7) In 1947, three researchers at Bell Labs, William Shockley, John Bardeen, and Walter Brattain, invented a point-contact transistor; one of the earliest applications of the transistor was for the AN/TSQ-51 Air Defense Command and Coordination System which relayed target coordinates from radar over to control center operators.[[8]](#endnote-8) Transistors, made up of semiconductor materials, were combined into logic circuits. These logic circuits of “transistors, resistors, and capacitors could represent numbers in binary form (on and off in a basic switch) and perform mathematical operations with them.[[9]](#endnote-9) These AN/TSQ apparatuses controlled the Nike missile batteries to be discharged in the event of a Soviet air attack.[[10]](#endnote-10)[[11]](#endnote-11) William Shockley, while working at Bell Labs, won a shared Nobel prize for inventing the first transistor, “a point-contact germanium transistor, in 1947,” and would later start up a transistor research and development company: Shockley Semiconductor Laboratory.[[12]](#endnote-12) This company was where Fairchild Semiconductor’s founders first met. They took their tacit knowledge of diffused silicon transistors and work connections gained at Shockley to found Fairchild Semiconductor.

A group of Shockley Semiconductor Laboratory senior staff members “included Gordon Moore, Jay Last, Eugene Kleiner, Jean Hoerni, Julius Blank, Victor Grinich, and Sheldon Roberts.” They penned a letter to Hayden Stone & Company, a New York investment bank asking the group for resources to enable them to produce “a line of silicon diffused transistors of ususual[sic] design applicable to the production of both high frequency and high-power devices.”[[13]](#endnote-13)

The idea of silicon diffused mesa transistors were not novel. Bells Labs’ researchers, Tannenbaum and Thomas, had already investigated batch processed, NPN mesa transistors. AT&T struck a deal with the U.S. government in 1955 and Western Electric had to release Bell Labs’ transistor and semiconductor patents to the public. By the time of the letter, June 1957, no semiconductor company had yet applied these patents to production.[[14]](#endnote-14)

Internal conflicts regarding William Shockley’s management style led to defections from Shockley Semiconductor Laboratory’s employees. Rather than seeking employment individually this group of seven decided to seek employment together before they were later convinced to start up a completely new company. Surveying this early group, their combined specialties included “physics, electronics, engineering, metallurgy, and chemistry.” Although highly technically skilled, none of this group had attended business school or had much prior business experience so the founders asked Hayden Stone to supply them with outside management. Ewart Baldwin, formerly at Hughes Semiconductor, joined Fairchild Semiconductor as its first general manager.[[15]](#endnote-15) Decades later in a 2007 anniversary panel, Jay Last recalled a real spirit of excitement in those formative stages, a chance to progress their semiconductor work without Shockley’s disruptions. Jay Last was one of the founders without a family to account for or any significant baggage preventing him from pursuing an untried, risky venture. Julius Blank candidly stated that: “I don’t think there was any fear at all, we were young then and didn’t know the difference.”[[16]](#endnote-16) While the letter originally sought to get another firm to hire the seven men as a group, upon meeting with the bankers Arthur Rock and Alfred Coyle, the ex-Shockley employees were convinced to start up their own company. They secured a contract with Fairchild Camera and Instrument in September 1957, which led to the creation of the Fairchild Semiconductor Corporation.[[17]](#endnote-17) Fairchild Camera and Instrument promised to provide loans up to $1,388,600 million for the first eighteen months but reserved the right to opt out of any loans thereafter. They also had the option to acquire Fairchild Semiconductor once it reached annual net earnings over $300,000.[[18]](#endnote-18) What they lacked in terms of size, momentum, or capital would have to be made up for in razor shape focus and a strong business vision.

As an upstart company, Fairchild Semiconductor had to quickly establish a niche to be competitive with already well-established companies like Texas Instruments and Hughes Semiconductor. The company’s distinct advantages included its strong technical skills and production knowledge base attained from prior experiences at Shockley. The original group knew that its best chance at success was the quick production of a marketable product, batch processed (mass manufactured), silicon diffusion transistors for digital computing.[[19]](#endnote-19)

With funding from parent company Fairchild Camera and Instrument, the founders purchased a building “at East Charleston Road on the border of Palo Alto and Mountain View.” The group also purchased specialized equipment for semiconductor fabrication processes such as photolithography, crystal growing, and diffusion.[[20]](#endnote-20) While the facility was being established, the team agreed to set Gordon Moore on the task of creating a diffused silicon mesa NPN transistor, while allotting Jean Hoerni the task of creating a PNP version. These initial products would be targeted at the military sector. At the time, in December 1957, when IBM Owego first met with the Fairchild group, IBM was subcontracting out components in data centers for the “SAGE air defense system,” as well as the computing systems for a successor to the B-52 long-range bomber. IBM Owego needed reliable, high power core driver transistors to function as “high freq power switch[es].” If Fairchild’s founders acted quickly, they would be able to leverage their unique knowledge of solid-state diffusion to manufacture “good matched PNP’s to go along with these [NPN transistors],” products which their closest competitors like General Electric and Texas Instruments could not readily produce without diffusion methods.[[21]](#endnote-21) IBM Owego required a saturation resistance of only 2 ohms, while the best silicon transistors of that time had saturation resistances of 100 ohms.[[22]](#endnote-22) The company’s founders believed that they could use diffusion methods to overcome the high saturation resistance obstacle.[[23]](#endnote-23)

A follow up meeting in February 1958 solidified the Fairchild team’s intentions to pursue the IBM core transistor as their first product. They promised to deliver IBM 100 sample transistors by August. The military’s emphasis on reliability compelled them to subject their product to a “1000 hour life test,” and delegated Fairchild founder, Victor Grinich, the task of developing testing equipment as well as transistor testing. Looking beyond the IBM order, Ewart Baldwin, Fairchild’s manager, charted a course for the company that focused on a rapid expansion of both professional staff and transistor production. According to Robert Noyce, the technology they were developing for IBM Owego could potentially be repurposed as a “low power,” “high speed,” “logic transistor” for digital computers in general.[[24]](#endnote-24) IBM Owego’s purchase order was confirmed on 2 March 1958, marking Fairchild’s first sale. Development of the NPN transistors required Fairchild’s founders to refine and standardize a complex fabrication methodology.

Much like vacuum tube production, semiconductor diode and transistor manufacturing were characterized by their incredible complexity; a single device could require dozens or even hundreds of steps from initial stage to finished product.[[25]](#endnote-25) The founders did most of the leg work in developing the early process and wrote out carefully phrased manuals for the production teams. Sheldon Roberts, with his MIT metallurgy doctorate, developed the process for growing silicon crystals. Jay Last articulated the process for creating silicon wafers out of the crystals while Jean Hoerni and Victor Grinich focused on transistor design elements.[[26]](#endnote-26) Julius Blank and Eugene Kleiner set up the machine shop and produced any needed equipment or fixtures while Gordon Moore handled the necessary “diffusion metallization, and assembly technology development.”[[27]](#endnote-27) Both Last and Noyce handled photolithography development, the careful removal of specific areas of the transistor’s silicon oxide surface with light.[[28]](#endnote-28) The time constraints imposed on them by IBM Owego and the company’s limited resources meant that the founders had to seek out creative solutions. Their early photolithographic setup used 16-mm movie camera lenses from a local San Francisco camera shop. These early, experimental methods meant that initial yields, “the proportion of ‘good’ devices emerging from the production line,” was highly inconsistent.[[29]](#endnote-29) Their early attempts at creating transistor junctions were fraught with current leakages and performance problems before they company tightened up manufacturing procedures and applied necessary engineering solutions.[[30]](#endnote-30) After Fairchild Semiconductor’s sale to IBM Owego, Ewart Baldwin convinced the founders to solicit additional funding from Fairchild Camera and Instrument for aggressive production expansion.

During a May 1958 policy meeting, Baldwin convinced the founders to agree to purchase a second, nearby facility. In doing so, Baldwin predicted that the transition to “high-volume manufacturing” would increase yields “from 20-25 percent to 65-70 percent” while also lowering the price of a single mesa transistor from “$150 per transistor…to $15 or even as little as $7.50 in in the second half of 1959.” These predictions were all based on Baldwin’s prior experience at Hughes Semiconductor, which was able to achieve the results he projected for Fairchild Semiconductor.[[31]](#endnote-31) Baldwin secured conditional support for a second facility from Fairchild Camera and Instrument. If Fairchild Semiconductor could sell “15,000-20,000 mesa transistors” and produce an “income of $500,000-$700,000” by 1958’s end, Fairchild Semiconductor would receive a new round of capital.[[32]](#endnote-32) Thankfully Fairchild Semiconductor successfully met IBM Owego’s August 1st deadline for the core drivers, shipping out “100 NPN mesa transistors.”[[33]](#endnote-33) Now that their first order had been fulfilled, the firm began the process of marketing and promotion to the public.

Their new products, coined 2N696 and 2N697, were “general-purpose transistors” meant to be used mostly in military electronics. A print advertisement for the product family emphasized their fast “switching rates,” “low saturation resistance” (a factor tied to application performance), and high temperature tolerances. The company overcame the military contractors’ aversion to unproven, new firms, securing “1,000 customer inquiries in less than three weeks.”[[34]](#endnote-34) In late August 1958, Robert Noyce and marketing manager, Tom Bay promoted their new NPN mesa transistor at Wescon, a large trade show. Noyce brought back positive news: their direct competitors presented no equivalent match to their offering.[[35]](#endnote-35) Fairchild Semiconductor’s products were superior to both Texas Instruments’ grown-junction silicon transistor, which used non-diffusion methods, as well as germanium transistors. Their products’ technical superiority and the untapped market opportunities of diffused silicon transistors afforded the company great success. By 1958, it had made $440,000 in sales, mostly to “military laboratories and military system contractors.”[[36]](#endnote-36) While these early successes provided the company with momentum, internal reliability engineers and eventually customers were reporting that some of the 2N696 and 2N697 devices were failing catastrophically.

Particulates of “dust and metal” would “short out” the base-collector junctions. While both production and engineering employees tried to minimize particle interference and implement more rigorous testing procedures, failure rates remained far too high. Transistors also inevitably slowed their switching speeds over time. Their minority carrier lifetimes, a transistor performance metric that should be kept low, rose during long term use and adversely affected switching speeds.[[37]](#endnote-37)

Jean Hoerni developed two innovations to solve these issues, gold doping and the planar process. By eventually integrating these techniques into its products, the company overcame these technical obstacles and made silicon the choice material for semiconductor manufacturing.[[38]](#endnote-38)

Gold doping as a concept had already been investigated at Bell Labs, which noted that gold could be used as a catalyst to reduce minority carrier lifetimes. Despite these findings, most people within the semiconductor industry viewed gold as an impurity to be completely purged from the finished transistors. Hoerni continued these prior inquiries to determine whether gold doping could improve his company’s transistors’ switching speeds; his experiments showed promising potential. The actual application of gold doping consisted of plating gold behind the transistor before “diffusing gold into the transistor’s collector region.”[[39]](#endnote-39) The rest of the company readily accepted Jean Hoerni’s surprising findings and integrated them into the new 2N1253 and 2N706 silicon mesa transistors. Silicon transistors which used gold doping were both cheaper and faster than the best contemporary germanium transistor designs. Fairchild Semiconductor would continue to use gold doping into the late 1960s before it was replaced by superior methods.[[40]](#endnote-40) The other concept Hoerni pioneered, the planar process, was momentous enough to almost immediately shift the company’s R&D and business strategy.

Jean Hoerni’s patent disclosure summarized the planar process’s general methodology and advantageous characteristics. The company’s 2N696 and 2N697 designs utilized the mesa architecture, which stripped away the silicon oxide layer on the transistor surface.[[41]](#endnote-41) The defining characteristic of the planar process was the preservation of the oxide layer as an “integral part of the device,” which protected the device’s “otherwise exposed junctions from contamination and possible electrical leakage due to subsequent handling, cleaning, canning of the device.”[[42]](#endnote-42) By January 1959, Hoerni was intent on creating a workable planar transistor with these ideas. By March 1959, he had succeeded in creating a functional NPN planar transistor. This NPN planar transistor proved to be much more reliable than Fairchild Semiconductor’s mesa transistors and also possessed superior electrical characteristics.[[43]](#endnote-43) Around the same time, in January 1959, Robert Noyce also began to conceive of another integral concept, the silicon planar integrated circuit.

The general idea of the integrated circuit came as an answer to one of Noyce’s conceptual questions, “Wouldn’t it be nice to be able to make the whole thing in one piece instead of having to fabricate it out of a lot of different pieces?”[[44]](#endnote-44) Integrated circuits combine the “active components and circuit traces,” standard elements of discrete circuits, and place them onto a single “small square or rectangular piece of silicon crystal.” Noyce was envisioning a complete circuit on one chip.[[45]](#endnote-45) Ddeas relating to “the possibility of realizing electronic functions in a ‘solid block’ of semiconductor material” were already floating around the industry. Other research leads such as Jack Kilby of Texas Instruments and Edward Keonjian, chief engineer for the American Bosch Arma Corporation, were also rigorously pursuing practical integrated circuits. U.S. military was also simultaneously stimulating electronic circuit miniaturization methods. They believed circuit miniaturization could decrease weight in their military equipment and increase reliability.[[46]](#endnote-46) Several developments already present at Fairchild Semiconductor enabled it to pursue their integrated circuit concept. First was “batch processing – making a lot of transistors at once,” or as Jay Last put it, a kind of mass manufacturing process of silicon wafers ala Ford Motors.[[47]](#endnote-47) The second was Jean Hoerni’s planar process, which provided transistor architectures more stability and reliability.[[48]](#endnote-48) Noyce’s initial integrated circuit model placed the circuit components within the protection of Hoerni’s silicon oxide layer and connected the individual components with metal lines(similar to wires) on the oxide layer surface.[[49]](#endnote-49) Convinced of the future potential of both planar process production as well as silicon integrated circuits, Fairchild Semiconductor’s management charted a new course.

By March 1959, Jean Hoerni demonstrated his “fully planar NPN transistor” to his peers, which immediately made their diffused mesa silicon transistor products obsolete. During a subsequent R&D Planning Meeting the group collectively decided to translate the planar process’s theoretical potential into a full fledge manufacturing process. They aimed to eventually planarize all their current mesa transistor products. This group also discussed a micro circuitry program which aimed to produce planar integrated circuits. This program was placed under the direction of Jay Last. The founders understood companies like Texas Instruments were already readying microcircuit demonstrations and Fairchild Semiconductor would have to act fast to avoid getting left behind.[[50]](#endnote-50) September 1959 was the date of another Wescon Conference and Fairchild Semiconductor unveiled new product models and planned directions.

The 2N706, a “NPN mesa transistor,” was a large improvement over the previous 2N696. The company’s engineers had dramatically shrunk the 2N706’s dimensions relative to the 2N696 and had improved its switching speeds with Jean Hoerni’s gold doping techniques. The company also exhibited experimental hybrid circuits, circuits which used a mixture of discrete active circuit components and passive circuit components, and tunnel diodes. Jay Last’s “20mc flip flop circuit containing four active elements and mounted in a TO-9 case” was a message to the greater industry that Fairchild Semiconductor was also a player in the microcircuit market.[[51]](#endnote-51) With the sudden departure of Ewart Baldwin in March 1959, Noyce took over as general manager and Gordon Moore took the R&D lead position.

Gordon Moore wrote a memorandum for the R&D program, reassessing research priorities and product focuses. In addition to active transistor development projects, Fairchild Semiconductor pursued “Microwave Devices and Special Diodes” and considered expanding into new computer memory developments.[[52]](#endnote-52) To stay competitive and address “problems effect[ing] yield, electrical performance and control reliability of our transistors and diodes,” Moore sanctioned a broad research effort into careful study of the properties of silicon oxide surfaces, silicon crystal growths, metallurgy, and diffusion, areas crucial to semiconductor fabrication. In another pivot away from prior strategy, Moore also advocated a commercial product program to diversify away from products solely targeting military buyers. This meant that Fairchild Semiconductor had to bring prices down for more cost-conscious consumers by cutting production costs and improving yields. Fairchild Semiconductor also focused on developing a line of microcircuitry products, components such as “flip-flops, gates, adders, shift-registers, and digital relay lines” that would “perform complete circuit functions.”[[53]](#endnote-53) Fairchild Semiconductor in late 1959 was in a prime position in the semiconductor market, with bolstered revenues and expanding production. Their original investor, Fairchild Camera and Instrument, decided to use their contracted clause to purchase Fairchild Semiconductor for the price of $3 million in stock.

By November 1959, the company was entering a new phase of development with Fairchild Camera and Instrument’s financial backing. The Mountain View plant received $75,000 to double their current space and Fairchild Semiconductor management was already planning to buy more acres for R&D facilities. The company also allocated $1 million to construct a 10-acre diode plant in San Rafael. Robert E. Freund, originally from Hughes Semiconductor’s silicon diode division, was brought in as assistant division manager. Irving Michaelson, who had prior experience with vacuum tube manufacturing at CBS, was also hired. Fairchild Semiconductor’s planned diode facilities demonstrated its renewed focus on mass production through low costs and high volumes. The company was looking to fulfill Moore’s stated goal of commercial market penetration and brought in experts from both the silicon diode industry and vacuum tube industry to run their diode division.[[54]](#endnote-54) Fairchild Semiconductor’s reputation and strong performance up through 1959 also benefitted their parent company, Fairchild Camera and Instrument. Fairchild Camera experienced a strong period of overall expansion and growth as it acquired new electronics companies and assets. Its stock price traded in the 20s in 1958 but almost constant growth by November 1959 left Fairchild Camera stocks trading in the low 200s. Wall Street investors saw high technology firms like Hewlett-Packard, Varian, and Fairchild Camera as rising industries throughout the 1950s and 1960s.[[55]](#endnote-55)

The original owners were now considered employees, and each founder received $250,000 worth of Fairchild Camera stock from the acquisition.[[56]](#endnote-56) The owners’ newfound financial independence and loss of stake in Fairchild Semiconductor’s further success led to the creation of numerous spinoff companies headed by former Fairchild Semiconductor owners in the early 1960s.[[57]](#endnote-57) By late 1959, Noyce was confident that the best direction forward for the company was microcircuitry.

Noyce asked Jay Last to form a Micrologic group tasked with designing “a family of hybrid circuits and a family of planar integrated circuits for digital computers in aerospace (primarily military) systems.”[[58]](#endnote-58) Lionel Kattner, one of the members of the Micrologic team, contributed the metal interconnections to Fairchild Semiconductor’s first flip-flop circuit. The group set out to fabricate a working direct-coupled transistor logic (DTCL) flip-flop circuit, with two pairs of transistors and a single resistor. Flip-flop circuits, with their two states of operation, could store a single bit of information, a 0 or 1. An early obstacle of the design stage was the insulation of the components from each other. Last first suggested a physical isolation method, filling a deep trench with an epoxy material.[[59]](#endnote-59) Using a long process (mostly chemical) of employing “epoxy, wave, photoresists, solvents (including acetone and trichloroethylene) and etchants (including hydrofluoric acid, nitric acid, and various mixtures of these acids)” as well as ammonium fluoride and boron and “phosphorus-based gases,” Lionel Kattner successfully fabricated the “first functional planar integrated circuit” in late May 1960. The yield of this process was quite poor; Kattner began “with 27 wafers, each containing 70 potential circuits” and there was only one successful flip-flop. Nonetheless, this single integrated circuit provided the necessary proof of concept.[[60]](#endnote-60)

Developments of these early flip-flop circuit designs revealed problems pertaining to their reliability and physical isolation methods. The Micrologic group by mid-1960 had begun to encounter issues with the epoxy, which would expand and contract during extreme temperature tests to mandated by military specifications. These resulted in broken interconnections and cracked silicon oxide layers. Isy Haas, another Micrologic team member, worked with Lionel Kattner to explore a method of “electrical isolation” which would use diffusion methods. The two of them began to develop a method which used alternating long diffusions of methyl borate. This step combined with photomasking techniques created a “P-type well that would isolate NPN transistors from eachother.” This new design looked very much like Jay Last’s “physically isolated integrated circuit” but the regions filled with epoxy were replaced with diffused silicon.[[61]](#endnote-61) By September 1960, Isy Haas and Lionel Kattner successfully fabricated fully functional electrically isolated flip-flops. Jay Last noticed these promising developments and funneled more resources to their electrical isolation initiative.[[62]](#endnote-62) While both technical design and fabrication of the integrated circuits were developing fruitfully, there were elements within the company that began to cast doubt upon Fairchild Semiconductor’s new focus on ICs and microcircuitry.

Jay Last was scheduled to give a talk to appease internal dissenting voices within the company and defend its new strategic shifts. During a September management meeting, head of sales and marketing, Thomas Bay voiced his displeasure. He fired “that the Micrologic program should be shut down.” Last’s talk surveyed their competitors, citing “RCA, Sylvania, and Varo.” RCA, with “$15.4 million in R&D contracts” from the military, was working on micromodules: “stacks of small ceramic plates, with electronic components affixed to the plates. These stacks were then encapsulated in plastic.” Sylvania was working to produce a compact “pancake” conception of the traditional transistor package to fulfill a Signal Corps contract. Varo Inc. was contracted by “the Office of Naval Research to make thin-film circuits…circuits in which transistors and passive components were formed from layers of film, deposited on a substrate.”[[63]](#endnote-63) Last also cited the potential cost savings and reliability gains from integrated circuits. He stated that integrated circuits would eventually be more reliable than hybrid circuits and require less semiconductor material.[[64]](#endnote-64) After the firm successfully began scaling production of its integrated circuits, demand for these products picked up slowly.

By 1961, the company had acquired only two major orders from both AC Spark Plug Division of General Motors and MIT’s Instrumentation Laboratory, which went on to construct an Apollo guidance computer using Fairchild Semiconductor Micrologic products. Integrated circuit sales in 1961 and 1962 were only $500,000 and $1.1 million respectively.[[65]](#endnote-65) Sales picked up dramatically after 1963 when the military forced contractors to use microcircuitry in its new weapon systems. Integrated circuits faced tough competition from hybrid circuits up through 1965, and leading semiconductor experts rigorously debated this rivalry at conventions like the International Solid State Circuits Conference. After 1965, semiconductor companies improved integrated circuit production and ICs became both cheaper and faster than both hybrid circuits and circuits with discrete components. Industry wide integrated circuit sales for the year catapulted to $120 million and continued at an astonishing rate in subsequent years.

Many of the innovations that Fairchild Semiconductor’s employees pioneered in their early years continue to be used in the modern semiconductor industry. Several of its original founders would go on to create monolithic, mainstay companies like Intel which further continued developments in miniaturization and consumer electronics.[[66]](#endnote-66) The pace of semiconductor and integrated circuit development at the time was moving quickly. Fairchild Semiconductor simply could not exploit every possible technological opportunity. Thus, it was common for Fairchild Semiconductor’s employees to split off and form companies such as Amelco Semiconductor and Signetics, both established 1961.[[67]](#endnote-67) Gordon Moore, speaking about Fairchild’s legacy, emphasized the development of the mainstay processes of fabrication such as lithography. Prior to the company’s arrival, lithography had “only been done in the laboratory” while Fairchild’s founders actually took these techniques into production.[[68]](#endnote-68) Noyce described how companies such as Philco were conceptualizing photolithographical techniques, “reproduce[ing] very fine geometric patterns just by taking a picture.” Fairchild Semiconductor repurposed these ideas to make double-diffused silicon transistors.[[69]](#endnote-69) Jean Hoerni’s planar process and its subsequent licensing to other companies allowed the technique to proliferate until it established itself as a mainstay of “modern billion-transistor microprocessors and memories” companies today.[[70]](#endnote-70)

Gordon Moore, while still at Fairchild Semiconductor, lent the modern semiconductor industry “Moore’s Law.” In 1965, using Fairchild Semiconductor’s data, Moore noted the growth trend of the “number of components per IC for minimum cost per component developed by Fairchild between 1959 and 1964.” After extrapolating the growth trend to 1975, he predicted “that the practical number of components per chip would reach 64,000, doubling every 12 months.” His follow up in 1975 proved his early prediction. Moore later adjusted his earlier hypothesis to state that integrated circuits’ transistor density would “doubl[e] every two years, rather than every year.” Moore’s Law compelled semiconductor companies to chase more complex, miniaturized architectures that would fulfill Moore’s Law. This driving concept has persisted as a driving force of the modern industry.[[71]](#endnote-71) Electronics today use integrated circuits with easily “tens of millions of components.[[72]](#endnote-72) Denser, more complex integrated circuits drive both performance improvements and cost reductions. This growth in high density chips fostered rapid miniaturization in digital electronics.

The first electronic calculating machines competed with old analog calculators in terms of cost “until the late 1960s.[[73]](#endnote-73) Advancements after the 1970s in chip density brought down electronic calculator costs. A hand-held calculator costed around $100 in 1971 but by 1975 it costed less than $5. The digital watch industry and video game industry also benefitted from the from the fruits of miniaturization.[[74]](#endnote-74) Developments at Intel in the late 1960s, founded by both Robert Noyce and Gordon Moore, created the enabling factors for personal computers, Microprocessors.

Intel’s Microprocessor, known as the 4004, was a programmable “general-purpose chip” that could be adapted for specific functions. It was advertised as “A microprogrammable computer on a chip." It was soon succeeded by the 8008 and 8080, which sported increased speed and superior bit processing.[[75]](#endnote-75) One of the earliest successful personal computers, the Altair 8800, contained an Intel 8080 processor and jumpstarted the PC revolution. Bill Gates described the impact of the Altair 8800 on the public at large and Microsoft in a 2004 periodical.

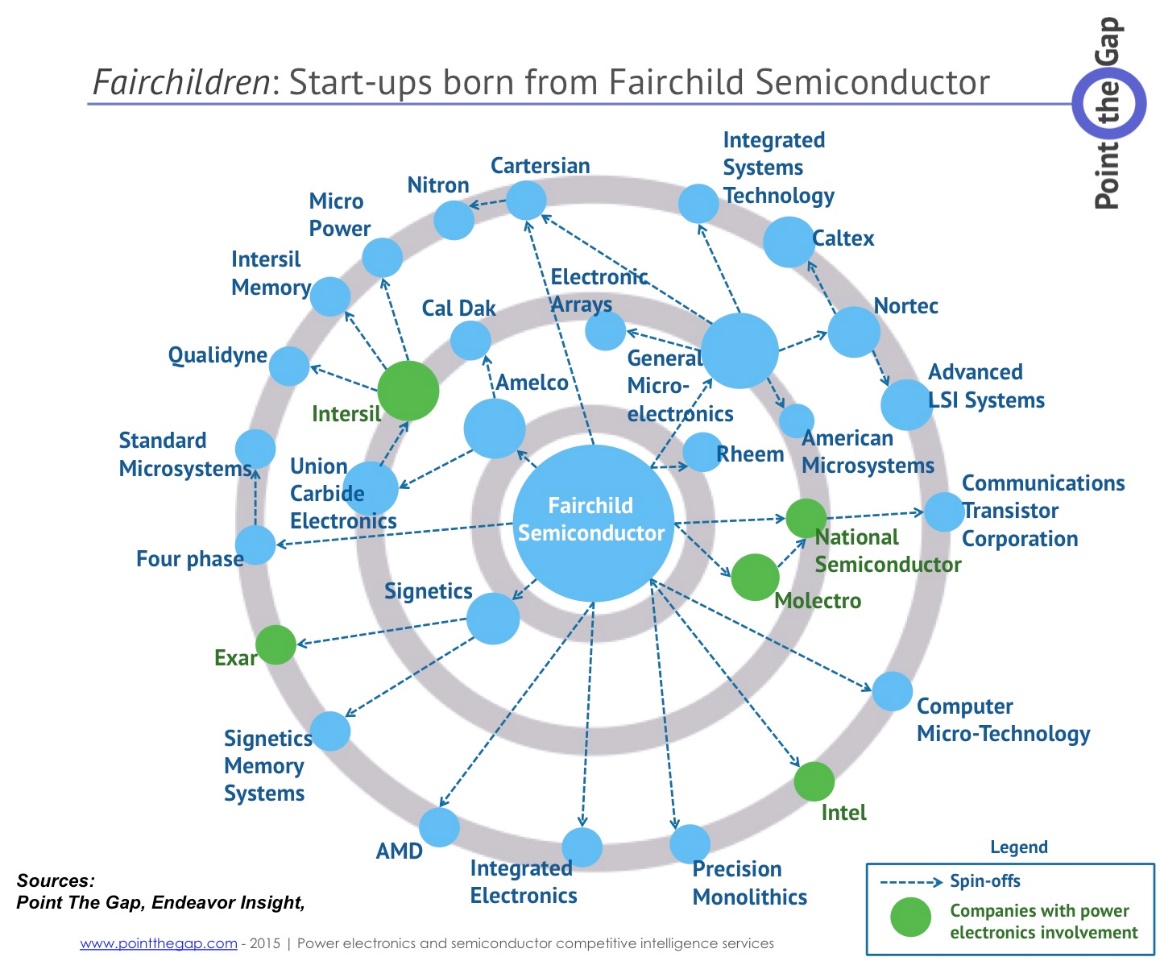
If you wanted a personal computer back in 1975, you had to build it yourself. For under $500 ($1,700 in today's money) you could mail-order a bag of parts that, after a few days' frustrating construction, became the **Altair** **8800**. Named after a star in a Star Trek episode, the **Altair** was a large blue box with no keyboard or screen. To program it, you flipped switches on the front and then read off the results on two rows of tiny red lights.

That doesn't sound like a very big deal today, and it wasn't that useful even back in 1975. But for me, the **Altair** was a revolution waiting to happen. Before then, computers often took up an entire room, and only trained technicians were allowed to use them. The idea of a small computer you could have all to yourself was enough to convince me to drop out of Harvard and start a company with my friend Paul Allen. We called it Micro-Soft.”[[76]](#endnote-76)

Bill Gates’ aspiration was to proliferate personal computing to the masses, “a computer on every desk and in every home.”[[77]](#endnote-77) Companies like Microsoft made their fortunes writing software for early PCs like the Altair while further innovations in ICs and Microprocessors made sure that PCs like the Altair and its successors were compact and affordable enough for domestic use.

Today we readily accept that offshore companies like Foxconn and Samsung produce our phone components and memory chips but Fairchild Semiconductor was one of the first companies to adopt the practice of offshoring labor.[[78]](#endnote-78) After establishing their initial Mountain View plant in 1958 and its San Rafael plant in 1960, the company constructed an assembly plant in Hong Kong. In 1966, they had 5,000 employees in Hong Kong and only 3,000 in California. Like modern general electronics and semiconductor companies today, Fairchild was looking to exploit “the highly skilled, low-cost labor pool in Asia.”[[79]](#endnote-79) Fairchild Semiconductor’s business strategy and overall organization was appropriated by other prominent semiconductor companies.

Fairchild Semiconductor acted simultaneously as a shaper and beneficiary of the Silicon Valley ethos. The company’s sharp focus on research and development, embrace of experimentation, and flexible management style have been replicated by “successor companies such as AMD, Intel, National Semiconductor,” and even Apple and Google.[[80]](#endnote-80) Most of the Silicon Valley’s top managers and engineers in the 1960s had cut their teeth at Fairchild Semiconductor. Startups like Intel and National Semiconductor were either spun off directly from Fairchild Semiconductor or were spinoffs of those spinoffs.[[81]](#endnote-81)



In surveying Fairchild Semiconductor’s early history, I aimed to frame historical events in the context of three areas. The first context was Silicon Valley’s growing high technology scene. Silicon Valley was simultaneously a vessel for and beneficiary of the firm’s ascendancy. It benefitted from Silicon Valley’s burgeoning light industry and business and technical developments in both radio and vacuum tube manufacturing. Fairchild Semiconductor’s founders, engineers, and managers in turn took their experiences and created new companies and initiatives. Analyzing Fairchild Semiconductor with an emphasis on business strategy, the company established a highly effective method to outdo their larger rivals, secure sales, and capture markets. By initially focusing on delivering a family of diffused silicon transistors, the firm was able to acquire enough revenue and capital to pivot into other semiconductor avenues. In 1961, the company had fully committed to integrated circuits, planar diodes, and planar transistors. Finally, viewing the company from a technical perspective shows how key innovations like the planar process and silicon integrated circuits created the paradigms of semiconductor manufacturing at modern firms such as Samsung and Intel. Fairchild Semiconductor’s combined contributions to each of these areas secure its position as a critically important agent of Silicon Valley and semiconductor developments.

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