Robery Noyce and Fairchild Semiconductor, 1957-1968

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Abstract:

Robert Noyce's career at Fairchild Semiconductor sheds light on several developments that were central to the growth of Silicon Valley and the semiconductor industry: entrepreneurship, technical leadership, and the management of growth in a high-technology company. His technical orientation, personal interest in new technologies, and hands-off management style helped establish a culture at the firm that welcomed innovations in research, process technology, manufacturing, and marketing. As Fairchild Semiconductor grew into a multi-divisional mass producer, Noyce's entrepreneurial leadership proved inadequate.

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Robert Noyce's career at Fairchild Semiconductor sheds light on several developments that were central to the growth of Silicon Valley and the semiconductor industry: entrepreneurship, technical leadership, and the management of growth in a high-technology company. Noyce served as Fairchild Semiconductor's first head of R&D and as its general manager for the six years of the company's most dramatic growth. His technical orientation, personal interest in new technologies, and hands-off management style helped establish a culture at the firm that welcomed innovations in research, process technology, manufacturing, and marketing. As Fairchild Semiconductor grew into a multidivisional mass producer, Noyce's entrepreneurial leadership proved inadequate. Communication breakdowns between divisions, coupled with a series of poor decisions by the parent company, further contributed to the decline of Fairchild Semiconductor.

On August 9, 1991, the state of California designated as its onethousandth historical landmark a nondescript two-story commercial building on a busy Palo Alto street. Among the 130 politicians and business leaders at the dedication ceremony were several who described how Fairchild Semiconductor, the company once housed at the site, had revolutionized the American semiconductor industry and contributed to the rise of Silicon Valley. A plaque laid at the site went so far as to claim that one of the company's inventions, the integrated circuit, "brought profound changes to the lives of people everywhere."1

Fairchild Semiconductor was the birthplace of the modern semiconductor industry. Semiconductors are elements such as germanium or silicon whose electrical properties can be altered by the addition of certain impurities. Products built from these elements-the earliest were transistors, resistors, and capacitors-can be strung together to build complete electronic circuits. As a class, the products themselves are also called semiconductors or, sometimes, semiconductor devices.

In 1958, researchers at Fairchild Semiconductor perfected the planar process, initially developed at Bell Labs, that made it possible to manufacture batches of semiconductors simultaneously. One year later, the company introduced the world's first practical integrated circuit, which combined in a single semiconductor device all the components needed to perform an electronic function. The integrated circuit, although initially extremely expensive, could pack together transistors, resistors, and capacitors much more tightly than ever before, which meant that goods using semiconductors could be faster, smaller, and more reliable than ever before.

Beyond the lab, Fairchild Semiconductor pioneered innovations that became industry standards in arenas as diverse as marketing, site selection, and manufacturing discipline. More than two dozen semiconductorrelated companies were started by former Fairchild Semiconductor employees eager to capitalize on their specialized technical knowledge. Many of these spin-off companies, collectively known in industry circles as the "Fairchildren," settled on the orchard lands of the fertile San Francisco Peninsula, contributing to the industrial development of the region that today is known as Silicon Valley.

Fairchild Semiconductor swung from wild success to dramatic failure. Nine years after its founding, the company employed some 11,000 people and generated more than $12 million in profits.2 One year later, the firm was struggling for survival.

No one is more closely associated with Fairchild Semiconductor than Robert ("Bob") Noyce, one of the company's eight founders. The firm's first director of research and development (R&D) and its general manager for seven years, Noyce was the company's most famous inventor, its public face, and its leader. His influence on Fairchild Semiconductor was as pervasive as the firm's on its industry.

Most treatments of Noyce have bordered on hagiography. The most famous account, by Tom Wolfe, is simply titled, "The Tinkerings of Robert Noyce: How the Sun Rose on Silicon Valley."3 The sole academic treatment of Noyce addresses his "supportive cultural leadership" of SEMATECH, a billion-dollar semiconductor manufacturing research consortium, which he headed from July 1988 until his death from a massive heart attack in June 1990.4 Only now has time granted us the objectivity to assess Noyce's career in the historical context of the corporate, industrial, and regional environments in which he worked.

For many years, studies of Fairchild Semiconductor were carried out by journalists, who tended to use the company as a convenient starting point for their histories of Silicon Valley.5 More recently, scholars have discovered Fairchild Semiconductor and have produced several excellent studies refuting the journalists' assumption that the company is of interest only as a means to an end. Ross Bassett, for example, has discussed technological and organizational developments at Fairchild Semiconductor in the context of contemporary developments at IBM and Intel. Daniel Holbrook has written about Fairchild Semiconductor's use of "diverse skills and knowledge that resided outside the firm."6 Christophe Lecuyer has argued that the technologists at Fairchild Semiconductor were but one of three groups (the other two being radio amateurs and microwave engineers) that led to the creation of California's most famous high-tech region.7

Although this degree of scholarly attention directed to Fairchild Semiconductor is relatively new, historians and economists have for several years been working to understand the growth of Silicon Valley and the development of the semiconductor industry. Stuart Leslie has identified both Stanford University, particularly Provost Frederick Terman, and military contracts as essential catalysts that ignited the electronics industry in the region. AnnaLee Saxenian has pointed to Silicon Valley's culture of decentralized, specialized firms, which she contrasts with the "autarkic," vertically integrated firms of Boston's Route 128, as key to the area's economic success.8 The editors of a recent anthology on Silicon Valley speak of the region's distinctive "habitat," in which "all the resources high-tech entrepreneurial firms need to survive and thrive have grown organically over time."9

An even larger body of scholarly writing has uncovered several features distinctive to the semiconductor industry during the 1950s and 1960s, such as low capital costs for new firms and liberal cross-licensing agreements. One of the most important aspects noted in this literature is that the Department of Defense and the National Aeronautics and Space Agency (NASA) significantly influenced the direction and pace of change early in the industry's history, either directly through R&D contracting, or (as was the case at Fairchild Semiconductor) indirectly as the single largest buyer of semiconductor devices. The military's influence waned as the industry matured, and consumer and industrial markets became increasingly important buyers of semiconductor devices.10

In short, research on both the semiconductor industry and Silicon Valley has focused on large-scale regional, economic, technical, organizational, and cultural developments. In their studies of Fairchild Semiconductor, Bassett, Lecuyer, and Holbrook have demonstrated how incremental scientific, process, and manufacturing improvements also led to significant changes in the industry. Their work has downplayed the contributions of any single individual at Fairchild Semiconductor by highlighting crucial day-to-day contributions by teams of founders, scientists, engineers or technicians, both inside and outside the company. Christophe Lecuyer, for example, disdains accounts that portray Fairchild Semiconductor "as the creation of a 'visionary' technologist-turnedbusinessman, Robert Noyce."11

Lecuyer, of course, is correct. Noyce was not the sole force behind Fairchild Semiconductor. The company possessed the incalculable advantages of place, personnel, and timing that Lecuyer and others have described so well-and Noyce was as much a product of those forces as he was a shaper of them. Noyce and his contemporaries had the good sense and good fortune to start a semiconductor company at a time when the Department of Defense (engaged in a mounting Cold War with the Soviets) began buying unprecedented volumes of transistors, and later, integrated circuits. Fairchild Semiconductor benefited from the state of California's massive outlays in infrastructure and higher education that attracted and trained technically capable immigrants from around the country, and indeed, the world. Some of the industry's brightest minds in the fields of research, marketing, and manufacturing worked at Fairchild Semiconductor during its heyday. Any account claiming that Noyce built the firm simply on the force of his own unique vision or talent is clearly inadequate.

Yet Fairchild Semiconductor was the site of more than simply the fortuitous intersection of Tongue durie historical forces. Entrepreneurs, Noyce among them, built the company.

Schumpeter argued that the individual actor is important for understanding the essence of capitalism, which is change.12 Nowhere is this more true than for the cluster of semiconductor firms that took root in the region now called Silicon Valley. Traditional methods of looking at business history that have tended to de-emphasize the role of individual entrepreneurs cannot capture the full story of Fairchild Semiconductor, the semiconductor industry, or Silicon Valley.13 A new approach that examines the contributions of key individuals, in concert with large-scale historical forces, is needed.14

If leadership is the missing ingredient in the existing academic studies of Fairchild Semiconductor, the missing leader is Noyce. Bob Noyce was a significant presence at the company he helped to found. His inventions and ideas helped to shape it. His charismatic presence attracted investors. His management style permeated the company. Over the course of two dozen interviews with several of the firm's founders, employees, and competitors, I have yet to meet anyone who thought that Fairchild Semiconductor could have succeeded without Noyce.

A close study of Noyce's leadership at Fairchild Semiconductor sheds light on three themes-entrepreneurship, technical leadership, and the management of rapid growth in a high-technology company-that were central to the growth of Silicon Valley and the semiconductor industry.

Founding, September 1957

Fairchild Semiconductor was founded in September 1957 by five scientists and three engineers who had resigned en masse from Shockley Transistor Laboratories, a company started by William Shockley, the coinventor of the transistor.15 Julius Blank, Victor Grinich, Jean Hoerni, Eugene Kleiner, Jay Last, Gordon Moore, Robert Noyce, and Sheldon Roberts had eagerly joined Shockley only little more than a year before, drawn by Shockley's sterling scientific reputation and his announced intention to build transistors using the then largely untried substrate of silicon and a new process technology called diffusion.16 Shockley had carefully assembled his team, hand-picking young men (none over age 30) with complementary skills in physics, metallurgy, chemistry, and electrical and chemical engineering. (In the late 1950s, there was no such creature as a semiconductor expert.) Years of research had convinced Shockley that every person had a "mental temperature"-the higher the intelligence and creativity, the higher the temperature-that could be determined through a series of tests and thorough evaluation of written work. He believed that these new employees, though generally inexperienced, were gifted with "hot minds."17

Figure 1.

William Shockley was a difficult boss.18 Subject to fits of temper, he switched the company's course from basic research projects to product development and back again. Shortly after launching the company, he decided to concentrate on a device he had invented called a "four-layer diode."19 His employees pointed out that the device was much more difficult to manufacture in quantity than the silicon transistor he had hired them to develop. Moreover, the customer base for the diode would be extremely limited, while the silicon transistor held great appeal not only for the U.S. military but potentially for a broad consumer market as well.20 Shockley paid no heed, pursuing what would become an Ahab-like obsession with the diode.

Meanwhile, three of Shockley's senior employees-Robert Noyce, Gordon Moore, and Jay Last-continued to work on the silicon transistor. Despite exciting progress, they knew their boss was either indifferent or hostile and thus kept many of their discoveries to themselves.21

By the summer of 1957, seven of the eight future Fairchild Semiconductor founders had decided to leave Shockley to try their hand at building silicon transistors elsewhere. (The odd man out was Noyce.) They wrote to the New York investment firm of Hayden, Stone, and Company, where Kleiner's father had an account, asking for help in finding a company to hire the group en masse.22

The letter was passed around Hayden, Stone, ultimately landing on the desk of a newly minted Harvard Business School graduate, Arthur Rock, who describes himself as the investment firm's version of a "resident scientific guru." Rock thought the most impressive element of the letter was "the fact that Shockley had chosen [the seven men when he] had the choice of almost anyone in the country."23

Rock and his boss, Alfred "Bud" Coyle, already interested in diversifying Hayden, Stone's investments to include electronics, flew to San Francisco to chat with the Shockley dissidents. By the end of the evening, the bankers had convinced the seven men to start their own company by finding a firm to act as their financial backer rather than directly hiring them. The young men, eager to stay in California, were excited at the prospect of starting their own local company.24

There was a catch, recalled one Fairchild founder: Coyle and Rock were concerned that they might "have a little problem selling this thing" to other bankers at the firm without being able to point to a clear leader among the group of seven Shockley defectors. "We [seven] said, \`We've got a leader but he feels a lot of obligation to Shockley. He ha[s] a title that we don't have [Director of R&D], and he is also a very sharp guy. He is not going to give away the store.'"25 The leader they were referring to was Robert Noyce.

From the moment he stepped through the doorway of Shockley Transistor, Noyce had been in a position of leadership, simply because he alone among the new hires was familiar with semiconductor devices. At MIT he had written a doctoral dissertation, entitled "Photoelectronic Study of Surface States on Insulators," and he had worked for three years in the semiconductor research group at Philco before coming to Shockley. In short, at a time when William Shockley felt the need to offer most of his employees basic lessons on the workings of semiconductors, Noyce already possessed both theoretical and practical knowledge of the devices, as well as a sense of how the technology could develop in the future.

Moreover, Noyce also possessed an easygoing confidence that, combined with his technical knowledge, made him stand out among his peers. "[Noyce] was one of these guys that could fit into almost any situation," said Gordon Moore, who recalled Noyce wearing shorts to work. "Everybody liked him the moment they met him."26

At Shockley, Noyce headed up a team that included much of the senior technical staff, all of them PhDs. He set the direction for the early silicon transistor efforts, and he helped recruit and set salaries for incoming technical employees.27 When Shockley asked the staff to rank its senior members in terms of technical leadership, Noyce emerged as the top choice.28 When Shockley attempted to reorganize the lab in the midst of rising mutiny from the seven disaffected employees, each scenario he considered named Noyce as "independent authority" or "manager" of the lab.29 When communications between Shockley and the seven broke down almost completely, Noyce served as go-between. Shockley's notebooks from this period are filled with entries like these: "Call to Noyce." "Noyce has only one suggestion." "Talk with Noyce."30

The seven Shockley defectors had invited Noyce to join them even before they talked to the bankers, but he had declined. His managerial responsibilities and relatively easy relationship with Shockley meant Noyce had more vested-both professionally and personally-in Shockley Labs than did the group of seven.

Sheldon Roberts was charged with relaying the conversation with the bankers to Noyce and asking him to reconsider joining. After a marathon late-night phone call (during which Noyce moved from agreeing to join, to backing out, to once again agreeing to join the dissidents), Noyce consented to attend a meeting with Coyle and Rock, scheduled for the following morning.31 At the appointed time, Roberts drove from house to house in Los Altos, Palo Alto, and Mountain View, picking up the future Fairchild Semiconductor founders, who rode squeezed shoulder-to-shoulder in the Roberts' family station wagon.

Banker Arthur Rock says that Noyce did not strike him as more brilliant or competent than the other seven men he met with that morning in a conference room at the Clift Hotel in San Francisco. Instead, he says, "What came through was that he was some kind of a leader and they looked up to him. He became the spokesperson."32 One Fairchild founder put things a bit more directly: Noyce, he said, "swung from being recalcitrant to becoming the big talker. The rest of us did not have anything to say after that point."33

The eight Shockley defectors and two bankers agreed they would try to start their own company. Rock pulled out ten one-dollar bills. Each man signed his name ten times. These ink-covered bills, Rock told them, were their contracts with each other.34

It was a propitious time to start a semiconductor company. Factory production of transistors had jumped 175 percent in the previous year. At the same time, transistor sales had zoomed 105 percent, to $7.1 million.35

The timing might have been good, but the strategy that Hayden, Stone had proposed was unconventional, to say the least. No standard operating procedure existed for this type of company-within-a-company undertaking. What accounting procedures would be used? How could the funding firm allow this group of unknown young men to run their own operation, according to criteria of their own devising, and not permit other employees the same autonomy? In the 1950s, with its ethos of conformity, this smacked of unseemly preferential treatment.36 Phone calls to roughly forty companies yielded no results.37 Meanwhile, the young men continued their work at Shockley.

At the same time, banker Bud Coyle happened to mention the scientists to playboy millionaire Sherman Fairchild. A meticulous man in his sixties, Fairchild was a bon vivant who frequented New York's posh 21 Club and wore "a fresh pretty girl every few days like a new boutonniere," according to Fortune.38 Fabulously wealthy (he was the largest shareholder in IBM), Fairchild was an inventor and founder of several companies based on his inventions. He suggested to the senior management at Fairchild Camera and Instrument, a maker of aerial cameras, that they talk to the group of eight from Shockley.39

Fairchild's suggestion came at a time of great change for the company, which was based in Syossett, New York. Sales were a satisfactory $43 million, but profits hovered at a negligible $267,000.40 A newly hired chief executive officer, John Carter, felt uneasy with the company's focus on defense work and looked hungrily toward the industrial markets to increase profits.41

Semiconductors were a logical choice for the expansion-minded company. The devices were increasingly making their way into the very missiles and satellites that used Fairchild Camera and Instrument's products and into the commercial and industrial markets that Carter coveted.42 Camera and Instrument had closely studied the possibility of entering the semiconductor field about six months before Coyle spoke with Sherman Fairchild and had decided the easiest way around years of basic research would be to expand through acquisition.43

Carter's technologically savvy second-in-command, Executive Vice President Richard Hodgson, was charged with "get[ting] the company into electronics."44 He flew out to visit with the eight Shockley defectors and was sufficiently impressed to invite Eugene Kleiner and Bob Noyce to visit Camera and Instrument's Syosset headquarters and Sherman Fairchild's luxurious home.45

After this meeting, Camera and Instrument entered into negotiations with the Shockley expatriates (or the "California Group," as they are called in the contract).46 Only when it was certain that some sort of a deal would be struck did the eight men decide to break the news to their employer. The task happened to fall to Gordon Moore, who recalls Shockley "leaving the building shortly after [our conversation] with his head hanging down and kind of a beat look on his face, and I just felt terrible about it."47

Moore's sympathy for William Shockley is revealing. Shockley's influence on Fairchild Semiconductor, while indirect, is undeniable. The eight Fairchild founders decided to work in silicon because this was the substrate they had used at Shockley Labs.48 They could bring a product to market so quickly, in part, because they had been trying to build this product together for the past year and a half at Shockley Labs, essentially behind Shockley's back. Fairchild Semiconductor's transistors were built with diffusion and thin-film techniques that the founders had learned at Shockley Labs.49 Noyce's very position of leadership at Fairchild Semiconductor could also be traced to Shockley, as could the complementary skills and high caliber of the founding team. Thanks to Shockley's foresight, the eight young men were extremely well prepared to take on the task of building silicon transistors.50 Wil_ liam Shockley, on the other hand, never succeeded in business. His company was dissolved in April 1960.51

On September 19, 1957, the Shockley defectors, representatives from Fairchild Camera and

Instrument, and bankers from Hayden, Stone met to sign papers establishing Fairchild Semiconductor Corporation. Each of the eight Shockley men owned 100 shares of stock in Fairchild Semiconductor (henceforth called Semiconductor). Hayden, Stone owned 225 shares, and 300 shares were held in reserve for key managers yet to be hired. Fairchild Camera and Instrument agreed to loan Semiconductor a total of $1.38 million over a period of eighteen months. In exchange, Camera and Instrument controlled the company through a voting trust.52 The parent firm received an option to buy all of Semiconductor's stock for $3 million dollars at any point before Semiconductor had three successive years of net earnings greater than $300,000 per year. If Camera and Instrument waited more than three years, but bought within seven years, the company would then have to pay $5 million for Semiconductor.53

Richard Hodgson advanced Noyce $3,000 to cover expenses until Semiconductor was formally organized, and Semiconductor continued for nearly eighteen months to receive a monthly check from Camera and Instrument: "like an allowance based on submitting accounts and this sort of thing," recalled Hodgson.54 However ad hoc and awkward this seems today, it was a workable method of cost accounting for what was, after all, a new type of business organization.55

Hodgson was named chairman of the new California-based semiconductor concern but would remain in New York. Noyce would serve as director of research and development and would have a seat on the board of Semiconductor (though not on Camera and Instrument's board). Press reports scarcely mentioned any founder but Noyce. The others were merely described as "also formerly with Shockley" or "associated with Dr. Noyce in the founding of the new company."56

There is no tangible reason why Noyce should have garnered the lion's share of attention as a founder of Fairchild Semiconductor. It was not his idea to leave Shockley; indeed, he came close to not leaving at all. He did not initiate contact with the bankers. He did not break the news to Shockley. He owned no more stock in Fairchild Semiconductor than any other founder, and although Hodgson had encouraged him to serve as Semiconductor's general manager, Noyce had declined, citing lack of experience.57

Noyce nonetheless was the logical choice to serve as Semiconductor's public face. He was a charismatic man who had spent a fair amount of time in the public eye, first as one of four sons of a Congregational minister in a small Iowa town, and later as a singer, actor, and champion diver at Grinnell College. Blessed with a natural flair for the dramatic-as a child, he lit his overworn model airplanes on fire and sailed them from the attic window-he attracted attention to himself even when he did not consciously try to do so.58 He was an expert skier, a passionate aviator, a chain smoker and a fierce competitor who hated to lose. He was a natural salesman who could, in the most casual of ways, inspire an interest and faith in his work that continued to awe some observers even ten years after his death. "People would follow him right off the edge of a cliff," says one former employee, shaking his head. "It was unbelievable."59 Moreover, Noyce seemed almost constitutionally unable to sit on the sidelines of any operation with which he was involved. As one person I interviewed said, "If he climbed in the boat, he would always be captain."60

Start-Up: Technical Leadership

Noyce's first job at Fairchild Semiconductor was precisely the same one he had held at Shockley Labs: director of research and development. By all accounts, he was an outstanding head of R&D, well respected for his offbeat-but at times surprisingly helpful-technical suggestions.61 He reviewed the monthly progress reports from each of the company's roughly half-dozen divisions and spent much of his time in a lab coat, engaging in the technical give-and-take in which he found great pleasure. Semiconductor cofounder and gifted physicist Jean Hoerni recalled Noyce as "a very good supervisor of technical people":

At Fairchild we had a lot of creative people, and he knew how to direct them in general terms, not specific terms. He was casual about it and didn't interfere. And as a result of this freedom came original thinking.62

During his tenure as head of R&D, Noyce patented an idea for an integrated circuit, a device that today nestles at the heart of the modern microprocessor like the tiniest doll in a Russian matryoshka. Noyce's great insight was that a complete electronic circuit could be built on a single chip, using specialized techniques (called planar processing) recently developed by his colleague Hoerni. Noyce's conception, and the subsequent two-year development effort to translate his ideas into practical reality, would eventually prove to be of monumental importance to Semiconductor and, indeed, to the entire electronics industry.63

Figure 2.

Shortly after Noyce conceived of the integrated circuit and patented it in early 1959, he left his formal technical responsibilities behind to assume the role of general manager at Semiconductor.64 ("I had to take over managing the project to make these things after he had come up with the ideas," recalls Gordon Moore.)65 Noyce nonetheless maintained a highly technical orientation as general manager; at this early stage in the young company's history, the presence of a technically knowledgeable man in a position of leadership was essential.

Consider, for example, Semiconductors decision to develop and market the integrated circuit Noyce had conceptualized. It was not at all obvious in 1959 that integrated circuits would be a good business for the young firm. Most straightforward calculations would have predicted yields so abysmal as to hinder the possibility of deriving any profits from integrated circuits.66 (The yield is the measure of functional devices on a chip. In the late 1950s and early 1960s, roughly fifty circuits could be simultaneously manufactured on a single slice of silicon. At each step of the complicated production process, a few of these circuits would fail. Thus, the yield was the percentage that successfully performed after the entire manufacturing process was complete.) Nonetheless, since Noyce and Gordon Moore (who assumed the job of R&D director after Noyce became general manager) were themselves technologists, they could appreciate the benefits that a functional integrated circuit would bring to the industry.

Customers would welcome the greatly reduced design and assembly costs, space requirements, and power needs, while manufacturers would appreciate the opportunity to increase the density of transistors on a single slice of silicon.67 It is a mark of the relative immaturity of the firm and the technical orientation of its management that Noyce and Moore, in consultation with Camera and Instrument's Hodgson, were willing to take a risk on the technology just because, as Moore puts it, the idea "was interesting and exciting."68

Managing Growth, 1959-1965

Fairchild Semiconductor grew astoundingly quickly in its first six years. Its early planar transistors cost roughly thirteen cents to produce (a dime of this was labor costs) and sold for $1.50-a 91 percent profit margin.69 In September 1959, after the company introduced seven new transistors and sold some $6,500,000 worth of its high-speed silicon devices (almost thirteen times the previous year's sales), Camera and Instrument decided to take advantage of the terms of its contract and buy its corporate stepchild outright.70 In a tax-free stock swap, the shares of Fairchild Semiconductor were traded for 19,901 shares of Camera and Instrument stock, with value equal to the $3 million purchase price agreed upon two years earlier. Semiconductor became a division (rather than a fully owned subsidiary) of Camera and Instrument, and each of the Semiconductor founders now owned Camera and Instrument stock worth roughly $300,000. Within weeks of the acquisition, the stock split two-for-one.71

By 1961, Semiconductor had more than doubled both its share of the world semiconductor market and the size of its product line. Its operations had expanded to seven locations that together occupied more than 200,000 square feet.72 Largely on the strength of the semiconductor division's growth, Fairchild Camera and Instrument boasted record highs in both profits ($3.8 million) and sales ($92 million). Its share price soared, and once again, the stock split two for one.73 One year later, sales were up another 10 percent, profits 14 percent, and more than 40 percent of Camera and Instrument's 7,400 employees worked for the semiconductor division.74

In 1965, net earnings for Fairchild Camera and Instrument topped $8 million-another record annual high. In the first ten months of 1965, the company's share price ballooned 447 percent, shooting from 27 to 144, with a 50-point growth in the month of October alone.75 Sales were at a record level, and at the same time, licensing fees for several important Fairchild patents provided an additional source of revenue.76 By year's end, only established industry giants Texas Instruments and Motorola surpassed Fairchild in the number of semiconductor devices manufactured per year.

Fairchild's astronomical growth reflected trends throughout the industry. The number of silicon transistors shipped from U.S. firms grew by a factor of 275 from 1957 to 1965.77 A two-tiered market for semiconductors emerged: at one end were mature products available at very low prices, manufactured in very high quantities, and with very low margins. These devices were often used in the entertainment marketas parts for radios, for example-and sold for less than a nickel apiece. On the other end were new devices, technically superior to the old, that were manufactured in smaller runs and sold at higher profits. These devices were used in military applications and also in the burgeoning computer market. Most firms in the young industry, including Semiconductor, served several markets and thus needed to function both as sophisticated research organizations and as mass manufacturers.

Semiconductor faced many of the problems common to fast-growing, young companies. The company was forever pursuing employees and space and searching for new ways to sell products and ratchet up production to support the demands of commodity manufacturing.

At the same time, Semiconductor faced a pressing industryspecific issue. Throughout the semiconductor industry in the early 1960s, a gap existed between R&D and manufacturing, and a strangely mystical aura surrounded the move from one stage to the other. The fact that a device worked in development did not automatically mean that it could be reliably manufactured in mass quantities.78 Problems appeared in the manufacturing fabrication facility ("fab") that simply had not existed in the lab.79 Sometimes the problems would disappear for no apparent reason, only suddenly to reappear.80 Solutions that worked one time might not work the next.81 Many elements of semiconductor manufacturing were so poorly understood that the problems encountered were given colorful names, such as "Purple Plague" and "Red Death." Scientists routinely referred to "black magic" and "witches' brew" in describing their process techniques.82 At Fairchild Semiconductor, the appearance of one problem after another in transferring a device or technique to manufacturing was so common that, at one point, Moore was happy to tell Noyce, "No new significant problems have arisen, which is a kind of progress."83

By 1961, Fairchild Semiconductor's R&D and manufacturing operations were not only in different buildings, but in different towns: R&D was in Palo Alto, and the manufacturing fab was in Mountain View. The tensions between the two sites ran deep.84 In April 1961, one researcher wrote, "The principal problem at the moment relates to the almost infinite number of meetings necessary to accomplish the transfer. I am frankly worried that our transfer procedure is plagued by meetings that must be attended by everyone to protect their positions."85

This gap between development and manufacturing contributed to a rapid proliferation of small companies spinning off from Semiconductor. By 1961, half of the founding team's members had departed to begin their own firms; by the end of Semiconductor's first decade, some two dozen companies had been started by former employees who left the company.86

Another factor contributing to the spin-off phenomenon was the booming stock market of the early 1960s, in which new electronics companies could raise capital on terms similar to those enjoyed by established firms. Indeed, the frenzy for electronics was so great at this time that the Securities and Exchange Commission was forced to issue a warning to consumers about "improper practices in the issuance and sale of space age stocks."87

The structure of the industry offered a third underlying explanation for the proliferation of spin-off companies. The same electronic circuit could be designed in dozens of different ways, using different combinations of transistors, resistors, and diodes. Silicon and germanium products competed for market share, as did various kinds of integrated circuits. The early 1960s also witnessed competition between integrated circuits and discrete components, such as transistors and diodes. One result of the great flexibility of circuit design was a highly differentiated marketplace, with thousands of different types of transistors, other components, and circuits for sale-and seemingly endless opportunities for new firms in search of niche markets.88 Indeed, the spin-off phenomenon, though particularly pronounced at Fairchild, was not limited to that company or to the region that would eventually be known as Silicon Valley. Semiconductor firms throughout the country were experiencing similar losses.89

Figure 3.

Semiconductor's status as a division of a larger firm posed its own challenges. CEO John Carter misinterpreted the success of the Semiconductor acquisition as evidence of his own ability to rescue struggling technical businesses. Consequently, at his behest Fairchild Camera and Instrument bought, and bought, and bought. The company expanded into graphic arts, space research, oscilloscopes, office equipment, and even home movie cameras. It bought a cathode tube company, and another that manufactured offset printing presses and other printing supplies. None of these acquisitions proved successful, and Semiconductor employees watched with disgust as the profits their division generated went to shore up foundering operations elsewhere in the newly sprawling company.

The parent company refused to distribute stock options as widely or generously as the management of Semiconductor requested. Although Fairchild Camera and Instrument had doubled the number of shares for which options might be granted when it acquired Semiconductor in 1959, only the most senior engineers, researchers, and managers were approved to receive options.90 As competition for employees in the industry increased, and as Fairchild's share price continued to zoom ever higher (thus raising the strike price of a new employee's options), Noyce and Hodgson repeatedly-and vainly-requested more stock options for distribution among employees throughout the Semiconductor division.91

As general manager of the rapidly growing company, Noyce encouraged innovation throughout the ranks. For the most part, he employed the same managerial approach that had served him well as head of R&D at both Shockley and Fairchild. He offered suggestions rather than barking orders, and he tended to speak in general terms, leaving the details to others. He did not follow up in a systematic way to confirm that promised work was actually delivered. Recalled one former employee: "He made the decision that you were the guy to do it, and he was confident you would do it [well]."92

Noyce personally was a highly creative man, renowned for throwing himself into leaps of logic so great that working with him was always invigorating and sometimes frustrating.93 He was forever looking to the future, always willing to stop what he was doing to chat about an employee's seemingly far-fetched idea. "If you wanted to talk to Noyce about flying to the moon using solid-state devices, he would stop and spend a half an hour with you talking about that," said Harry Sello, who worked at both Shockley and Fairchild. "I knew he had other things to do."94

Noyce's laissez-faire management style and focus on innovation, which played to his own entrepreneurial strengths and appealed to the creative instincts of many Semiconductor employees, was adopted in other parts of the company. It is thus perhaps not surprising that the firm developed a highly innovative culture. An employee whose name would have appeared far below Noyce's on a corporate organization chart recalls:

Leadership at the top is what gave us the ability to do our job the way that we thought it was best to do .... You could say that in one sense, management didn't know any better; we were the experts, and they let us do it. Everyone was inventing how everything was to be done.95

By one estimate, Semiconductor's R&D labs were responsible for fully 16 percent of the major innovations in integrated circuit technology during the period 1960 to 1977.96 One researcher recalled that company policy "was to allow PhDs to play with their 'toys' [ideas] for about a year," although as Ross Bassett has pointed out, management gently steered researchers towards a "universe of acceptable projects" and occasionally reminded them to stay within its borders.97

Divisions outside of R&D were highly innovative. The company offered customers unmatched technical support, for example, including with each product highly detailed technical manuals that were so popular that Semiconductor highlighted them in advertisements for the products themselves.98 In 1964, Semiconductor replaced the industry's traditional product-based marketing structure with an applicationbased selling approach. Instead of a diode or transistor sales manager, for example, Fairchild would have an entertainment consumer market manager or a military market manager.99 In 1967, the company broadcast one of the world's first "infomercials"-a half-hour "Briefing on Integrated Circuits," designed to update and entertain engineers with chipper discussions and colorful illustrations of the state of the art in integrated circuits.100

The range of innovations at the company was remarkable. In 1963, in a move that surprised many in the industry, Semiconductor opened a test and assembly plant in Hong Kong, following up on a suggestion by Noyce.101 Moving this work offshore offered a means of reducing the industry's most significant costs-the labor needed to assemble and test the devices-without resorting to automation. A brief experiment with a "semi-automatic assembly line" at the transistor plant in 1960 had convinced manufacturing head Charlie Sporck that the up-front costs of automation were daunting and the payoff uncertain, since production processes changed so quickly that machines installed one year might require retooling the next.102 Fairchild's offshore move was quickly imitated by other major semiconductor firms, including Motorola, Philco-Ford, Signetics, Transitron, and Raytheon.103

The focus on innovation led Semiconductor to reject most direct government contract work. Whereas in other firms government contracting might constitute the primary source of R&D funding, at Fairchild Semiconductor, Noyce told a reporter in 1963, less than 10 percent of current business was directly contracted by the government, "and we like it that way."104 A visitor to the company in 1965 said that Noyce seemed to believe there was something almost "unethical" about using government contract money, rather than private capital, to fund R&D. Noyce also feared that government contracts would limit the firm's creative flexibility to explore what he called "interesting slop" that might unexpectedly emerge in the midst of research.105 This attitude toward direct government contracting was highly unusual for a semiconductor firm in the 1960s, and the visitor commented that the company reminded him of a "little boy" who just did not understand the way the business was supposed to work.106

That Semiconductor did not take kindly to direct contract work does not mean that the military had no influence on the company. When Semiconductor did accept contracts, it often found the work itself useful.107 Moreover, Semiconductor, like many companies, almost certainly used government funds to support work it would have undertaken anyway.108 Military work at times reshaped corporate structure and work methods at Semiconductor: when the firm was chosen to participate in the Minuteman Reliability program, for example, it set up a "Reliability Evaluation Department."109 The military could also help determine product design: for instance, Christophe Lecuyer has convincingly shown that Semiconductor worked closely with military contractors in designing and building its integrated circuits.110

Finally, the federal government was an important customer for Semiconductor, even when the firm did not directly contract with the military. The vast majority of Fairchild Semiconductor's early customers were aerospace firms buying products to use in their own government contract work, and these customers developed specifications that reflected military requirements.111 Fully 100 percent of the early integrated circuits (which Semiconductor pioneered) went to military uses. While Semiconductor assiduously courted the industrial and commercial markets, its products nonetheless could also be found in surveillance radar and transmitters for space vehicles; in Polaris, Minuteman, and Advent missiles; and in the MAGIC airborne inertial guidance computer, as well as the MARTAC missilecontrol computer.

As general manager, Noyce played an important role in some of these decisions. In others, such as the development of distribution programs, he had little influence. The point is not that Noyce was directly responsible for all the company's innovations but that he built a culture that welcomed them.

Noyce, of course, did not run Semiconductor alone. Manufacturing head Charlie Sporck, who had joined the firm from General Electric in 1959, took on an increasingly important role as Semiconductor faced growing pressure to streamline manufacturing operations in light of the huge volumes in production.112 A strong-minded, detailoriented man, Sporck built a manufacturing operation at Fairchild that, over time, came to emphasize cleanliness and production control.113 Sporck also maintained a productive-albeit tempestuousworking relationship with marketing chief Tom Bay, a technically savvy, impeccably dressed former professor.114 Along with Gordon Moore, who headed R&D, these men coordinated daily operations at Fairchild Semiconductor.

A Bungled Transition, 1965-1968

By the mid-1960s, Semiconductor was struggling to become a mass producer of commodity semiconductor devices. At the same time that the firm was shipping hundreds of thousands of devices per week, it maintained essentially the same organizational structure it had developed as a tiny start-up operation.115 All manufacturing reported to a manufacturing manager, all engineering to an engineering manager, all design to a design manager. As the gap between development and manufacturing revealed, the different divisions of the company did not readily coordinate operations. There were no product managers to ensure that a product moved efficiently from conception through shipping. The only person with responsibility for more than one division was Noyce himself, and his managerial style did not lend itself to the sort of detailed coordination the company needed.116

In 1965, Noyce was named a vice president of Camera and Instrument, which extended his authority to a new instrumentation division, headquartered in Clifton, New Jersey. Noyce began to spend the bulk of his time on the East Coast. 117 He tapped Sporck to become Semiconductor's new general manager and asked marketing head Tom Bay to run the instrumentation division. With this move, the two men, whose skills had complemented each other's and Noyce's so well, were separated, leaving a vacuum within day-to-day management at Semiconductor.

At the same time, Camera and Instrument began a new stock option plan that was less generous than the old. Specifically, the company reduced the number of shares available for options by 25 percent, even while adding employees at a rate of 2,000 per year.118 The lowest strike price under the new option plan was higher than the highest price under the old option plan. One year later, the value of employees' stock holdings was diluted even further when the company issued almost 260,000 more shares of common stock.119 At the same time that the Fairchild plan was fading, every company in the semiconductor industry was engaged in recruiting efforts so desperate that one reporter described them as "probably absorb[ing] as much energy as new product development."120 While younger electronics companies, including the Fairchildren, could offer rich options packages to new recruits, Semiconductor had problems securing them even for experienced engineers.

Semiconductor's welfare was further jeopardized by the production gap between R&D and manufacturing, which had been growing for years and, by 1965, yawned positively cavernous.121 Relations between development and manufacturing had become so confused that communications were breaking down. Moore complained of "the lack of attention as to what was done with the devices sent from R&D to Mountain View."122 Historian Ross Bassett has shown convincingly that basic research and development work took place in the manufacturing facility that "was not only not under the management control of R&D [which should have been overseeing the projects], it was under no management control whatsoever."123 Some of this basic R&D work yielded exciting results that should have made Semiconductor a leader in the new field of metal-oxide-silicon [MOS] process technology, which today is used to build most semiconductor devices. Because this research work took place outside the standard R&D channels, however, its funneling into the corporate production pipeline was delayed.124 As a result, the company ended up lagging in a field that one of its former employees had pioneered.125

As general manager, Sporck used the product-manager model made famous by Procter and Gamble to reorganize Semiconductor. He designated several product managers, all of them engineers, to coordinate production of their specific devices. The reorganization did not fully decentralize the Semiconductor operation, since marketing and production control (which determined the volumes of devices to be manufactured) maintained centralized operations.126 Nonetheless, it was a significant change from the organizational structure under Noyce.

The changes came too late. By the end of 1966, Fairchild began to miss its promised deliveries, at times meeting only about one-third of its customer commitments.127 At the same time, the company failed to market several new products developed in R&D because the process of transferring from development to manufacturing was so inefficient that the devices were never manufactured in volume.128 Indeed, Semiconductor's difficulties in bringing its own inventions to market were so renowned that they generated an oft-repeated industry one-liner: "The first parts coming out of Fairchild R&D were probably made in Sunnyvale." Sunnyvale was home to Signetics, yet another spin-off from Semiconductor.129

By the end of 1966, Semiconductor's festering troubles had become apparent even to outsiders. In the fourth quarter, Camera and Instrument's profits dropped below those of the third quarter, and the parent company, according to one report, "placed the blame at the doorstep [of Semiconductor], saying the division was having serious problems in production of integrated circuits and its product mix was topheavy with low-profit items."130 The Camera and Instrument annual report referred obliquely to "problems encountered in the introduction of new processing facilities and new semiconductor devices [that] had to be overcome." At the urging of Camera and Instrument, Semiconductor initiated "FAIRCHILD 71," which it described as a five-year plan and the launch pad for "a concentrated program of process cost reduction and mechanization [that] established definitive guidelines for expansion."131

A command to reduce costs infuriated the Semiconductor employees. For years, the Semiconductor division had been more profitable than the company as a whole, with other divisions losing money and serving as net drains from the Semiconductor bottom line."' Nor did the Semiconductor division have a formal representative on the parent company's board to voice the division's concerns and interests. Although another vice president of the corporation served as a director, Noyce did not.133

One vice president of Kidder, Peabody spoke for many in the investment community when he said, "If I could just buy the semiconductor division, I might do it, but I can't see paying a premium for Fairchild's management and all the uninteresting stuff you have to take with semiconductors."134

In March 1967, a disgusted Charlie Sporck quit to become CEO at the moribund National Semiconductor, taking with him several key integrated circuits men.135 For months Sporck had been complaining about how hard it was to attract new people with the Fairchild options package.136 He resented that Camera and Instrument was "throwing away in various directions" money made by the sweat of his brow at Semiconductor.137 Moreover, he recalls watching the rising fortunes of Semiconductor's spin-offs and wondering, "Why don't I do that sort of thing?"138 Why not indeed?

Sporck's departure was personally very painful for Noyce, who leaned heavily on his strong second in command.139 Rather than looking for another manufacturing expert, Noyce named Tom Bay, his former marketing lieutenant, as general manager of Semiconductor, a move that did not ease the division's troubles.140 "I just felt that things were falling apart," Noyce would later say of the months following Sporck's departure. Noyce knew that there was no way he could keep high-caliber employees at Semiconductor much longer: the offers from outside were simply "too enticing" and the situation at Semiconductor too dismal.141

Noyce was a highly creative man who by 1967 found himself functioning in an almost purely reactive mode: assimilating acquisitions he did not want in the first place, fighting to keep employees, and wrestling with Camera and Instrument management over stock options. There was no joy in such work. He felt out of touch with the innovative, technical side of Semiconductor, and he missed it. No doubt it was around this time that Noyce began to consider leaving Semiconductor.142

While Noyce plotted privately, he urged Camera and Instrument to take steps to soften the blow of Sporck's departure for the rest of the Semiconductor employees, some of whom he knew were wavering. Camera and Instrument, for its part, took decisive action. Noyce was given a seat on the board, and shortly thereafter, the directors pushed through a vast democratization of the stock option plan, authorizing 300,000 additional shares for options.143 The board even entertained a promising proposal to sell a large stake in Camera and Instrument to ITT (a planar licensee), with the understanding that all non-Semiconductor divisions would be sold off. The deal failed.144

In any case, it was all too late to stanch what had become a hemorrhaging of employees from Semiconductor. Six months after Sporck's departure, some thirty-five people had left to join him at National.145 Employees began fleeing Semiconductor from almost every possible exit door. "Suddenly," wrote Business Week, "every semiconductor company in the Bay area was able to hire Fairchild professional people."146 Semiconductor's fortunes plummeted quickly. In late March of 1967, the company announced that several production difficulties had been overcome, but the announcement went largely unnoticed in a tide of bad news.147 The industry was in the midst of a terrible slump that hurt not only Semiconductor, but also many of its competitors. An unanticipated drop in consumer demand meant many customers no longer needed the devices they had ordered.148 In October, Semiconductor, for only the third time in its ten-year history, reported monthly losses.149

Thanks in large measure to Semiconductor's slipping performance, Camera and Instrument's earnings for the third quarter of 1967 were a paltry $137,000-down a staggering 95.5 percent from the preceding year's third-quarter profit of $3 million, and a worse performance than an already leery Wall Street had expected.150 With the company barely breaking even, the stock price slid to 52 from 92 3/8 at the beginning of the year.151 By year's end, Camera and Instrument, admitting that the semiconductor division accounted for well over half of the company's sales, reported a $7.7 million loss.152 Some $4 million of this were write-offs, but the remaining $3.5 million trail of red ink compared to a profit the previous year of more than $12 million. The company described the results as "a deliberate attempt to group all losses and take the beating at one time."153

In the wake of the appalling third-quarter earnings report, the board of Camera and Instrument ousted the company's high-living CEO, John Carter, and asked Richard Hodgson, the man who first lured the Shockley defectors to Fairchild, to add CEO to his title of president.154 Not more than six months later, Hodgson was stripped of power and told to report to an "office of the chief executive," which consisted of four Camera and Instrument directors: Noyce, Walter Burke (Sherman Fairchild's personal investment advisor), Joseph B. Wharton (a financial and tax consultant), and Sherman Fairchild himself. Meanwhile, the board launched a search for a permanent CEO.

At the same time, everyone at Semiconductor, in the industry, and on Wall Street had expected Noyce to be named CEO-and with good reason. No longer was he a scientist-in-a-business-suit. He was a director of Camera and Instrument, architect of what had been one of the world's most successful electronics companies, and one of the most respected men in his industry. Noyce was, in short, the logical internal candidate. Although the people who worked most closely with Noyce agreed that he was a better leader than manager, they nonetheless thought he should be offered the job.155

Although Noyce was under consideration for the top spot, the board ultimately decided that Noyce might "be considered as presidential material someday," but not yet.156 Whatever Semiconductor's current problems, in Noyce's estimation they paled in the face of the firm's previous phenomenal successes, and so he was "kind of ticked off," as Moore recalls, not to be offered the job as Camera and Instrument's CEO.157 The slight, coupled with the ousting of Hodgson, a Semiconductor ally, confirmed Noyce's long-held suspicions that the Camera and Instrument board had absolutely no idea of what they were doing and no appreciation of the fact that for years Semiconductor had been the tail wagging the corporate dog.158

According to one version of events, an irritated Noyce went to Sherman Fairchild and resigned in person, but the chairman (who by now was on the verge of panic) asked Noyce to stay on long enough to find a replacement CEO.159 Noyce offered his own suggestion for the position-C. Lester Hogan, the general manager of the powerhouse semiconductor division at Fairchild's archrival, Motorola-and even arranged a meeting between Camera and Instrument director Walter Burke and Hogan. Hogan, however, had no interest in the position.160 Motorola's Phoenix-based semiconductor operation was already bigger than Fairchild's, and it was not encumbered with aerial cameras and printing supplies. Sherman Fairchild flew down to Arizona in an attempt to change Hogan's mind. Hogan demurred. Finally Noyce flew to Phoenix and spoke frankly about the company and his own reasons for leaving. He urged Hogan to consider the job.161

Hogan ultimately negotiated a compensation package from Fairchild Camera and Instrument so extraordinary-an estimated $120,000 annual salary, plus 10,000 shares of stock and an interest-free loan to buy options on another 90,000 more-that it was reputedly immortalized as a distinct unit of measure, the "Hogan." (As in, "That guy can't be worth more than half a Hogan.")162 He brought with him to Fairchild every senior manager from Motorola's semiconductor operation, save one.163 He even convinced Camera and Instrument to move the corporate headquarters to the Bay Area-tangible evidence of the pivotal role of the Semiconductor division in the corporation.164 Even given the spectacular deal he finessed, Hogan insists, "I wouldn't have gone if Bob Noyce, if ... I had great respect for Bob Noyce and he's a great salesman."165

Noyce formally resigned from Fairchild on June 25, 1968. He included with his brief formal letter of resignation a heartfelt two-page missive addressed to Sherman Fairchild. Noyce told Fairchild that he wanted to find or start a smaller company, a place where he could 11 get close to advanced technology again" and enjoy "more personal creative work in building a new product, a new technology, and a new organization."

One month later, he and Gordon Moore, with the assistance of Arthur Rock (who had established a private venture capital firm on the West Coast), launched N-M Electronics, a semiconductor memory company they soon renamed Intel. Noyce and Moore decided to structure Intel as a "two-headed monster," with power and stock split evenly between them.166 While Moore coordinated day-to-day operations at the company, and Andy Grove (who had worked for Moore at Semiconductor) oversaw the fab, Noyce met with customers, analysts, sought-after recruits, and reporters. The bigger Intel grew, the further Noyce pulled back from active management. In 1975, when Intel boasted profits of almost $137 million and employed some 4,600 people, he became board chair, leaving the presidency to Moore. In 1979, with Intel's net revenues at $663 million and an employee base of more than 14,000, Noyce stepped down to vice chair.167 By the year 2000, Intel, its business now centered around microprocessors, had facilities in more than thirty countries and a net income of $10.54 billion.168

Conclusion

Fairchild Semiconductor was launched and sustained by a remarkable record of what Joseph Schumpeter called "creative destruction." The firm's entrepreneurs built on Bell Labs research and developed their own cost-efficient process technologies. They combined innovative marketing with manufacturing discipline. In doing so, they helped to develop a new industry that, in turn, reshaped the electronics industry and the once bucolic valley south of San Francisco.169

This entrepreneurial culture had significant drawbacks, most succinctly described by Alfred Chandler's observation that "Fairchild's problem was that it produced entrepreneurs, not products."170 The firm's focus on innovation contributed to a culture that privileged research over manufacturing and disdained such routine but important work as knowing inventory levels or the status of an order.171

Noyce is accountable for both the beneficial and detrimental aspects of Fairchild Semiconductor's innovative culture. The very openness to new ideas that contributed to his success as a leader and entrepreneur hampered his ability to manage a large organization, as he later admitted:

One thing I learned at Fairchild ... is that I don't run large organizations well. I don't have the discipline to do that, have the follow through .... My interests and skills are in a different place, that's all. It's getting people together to do something, but that only works for me in a smaller group.172

Noyce also placed a good measure of blame on the management of Fairchild Camera and Instrument. He told Sherman Fairchild that the parent company had grown erratically and irresponsibly, that it had denied Semiconductor the incentives it needed to keep employees, and that it had commandeered Semiconductor's profits to carry other divisions, rather than plowing them back into the division. "I believe this has caused our difficulties," he said, characteristically careful never once to name a specific person or group of people whom he would hold personally responsible.173

Bob Noyce's role at Fairchild Semiconductor underscores that an individual can significantly shape the development of a corporation that in turn shapes the development of an industry and a region. The company's performance reflected a great number of influences: for example, the demands of its parent company, the requirements of the U.S. military, and the innovations of its employees. It is not mere coincidence, however, that Fairchild Semiconductor excelled as an entrepreneurial organization and faltered as it matured. These developments mirrored the strengths and weaknesses of its leader, Robert Noyce.

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1San Francisco Chronicle, 10 Aug. 1991; Peninsula Times Tribune, 10 Aug. 1991; plaque at 844 Charleston, Palo Alto.
2Fairchild Camera and Instrument Annual Report 1966.

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3Tom Wolfe, "The Tinkerings of Robert Noyce: How the Sun Rose on Silicon Valley," Esquire, Dec. 1983, 346-74. The article ran next to profiles of other "American Originals," including Jackie Robinson, John F. Kennedy, Betty Friedan, Walt Disney, Elvis Presley, and the brothers Rockefeller. This heroic image of Noyce persisted throughout his life. See, for example, Otis Port, "Bob Noyce Created Silicon Valley. Can He Save It?" Business Week, 15 Aug. 1988, 76.
4Janice M. Beyer and Larry D. Browning, "Transforming an Industry in Crisis: Charisma, Routinization, and Supportive Cultural Leadership," Leadership Quarterly 10 (Spring 1999): 483-520.

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5For a sampling of book-length journalistic and popular historical accounts of the rise of Silicon Valley, see Michael S. Malone, The Big Score: The Billion Dollar Story of Silicon Valley (Garden City, N.Y., 1985); Dirk Hanson, The New Alchemists: Silicon Valley and the Microelectronics Revolution (Boston, 1982); Everett M. Rogers and Judith K. Larsen, Silicon Valley Fever: Growth of High-Technology Culture (New York, 1984).
6Daniel Holbrook, "Diversity, Complementarity, and Cooperation: Materials Innovation in the Semiconductor Industry," in Andrew Goldstein and William Aspray, eds., Facets: New Perspectives on the History of Semiconductors (New Brunswick, N.J., 1997), 77.

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7Christophe Lecuyer, "Making Silicon Valley: Engineering Culture, Innovation, and Industrial Growth, 1930-1970," unpublished Stanford University diss., Aug. 1999, chs. 3-4; Ross Knox Bassett, "New Technology, New People, New Organizations: The Rise of the MOS Transistor, 1945-1975," unpublished Princeton University diss., Jan. 1998. Another interesting piece, written by Gordon Moore, who cofounded both Fairchild Semiconductor and Intel (with Noyce) is "The Role of Fairchild in Silicon Technology in the Early Days of 'Silicon Valley,"' Proceedings of the IEEE 86 (Jan. 1998): 53-62.

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8Stuart W Leslie, The Cold War and American Science: The Military-IndustrialAcademic Complex at MIT and Stanford (New York, 1993); "How the West Was Won: The Military and the Making of Silicon Valley," in William Aspray, ed., Technological Competitiveness: Technological and Historical Perspectives on the Electrical, Electronics, and Computer Industries (Piscataway, N.J., 1993); AnnaLee Saxenian, Regional Advantage: Culture and Innovation in Silicon Valley and Route 128 (Cambridge, Mass., 1994); and "The Genesis of Silicon Valley," in Peter Hall and Ann Markusen, eds., Silicon Landscapes (Boston, 1985), 20-34. This work is part of a much larger body of research on industrial districts. For an excellent study of the interactions among specialized suppliers and their customers in an industrial district, see Philip Scranton, Figured Tapestry: Production, Markets, and Power in Philadelphia Textiles, 1885-1941 (New York, 1989).

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9Chong-Moon Lee, William F Miller, Marguerite Gong Hancock, and Henry S. Rowen, "The Silicon Valley Habitat," in Chong-Moon Lee, et al., eds., The Silicon Valley Edge: A Habitat for Innovation and Entrepreneurship (Stanford, Calif, 2000), 3. For information on distinctive features of the semiconductor industry, see Richard N. Langlois and NA. Edward Steinmueller, "The Evolution of Competitive Advantage in the Worldwide Semiconductor Industry," in David C. Mowery and Richard R. Nelson, eds., Sources of Industrial Leadership: Studies of Seven Industries (Cambridge, U.K., 1999), 21. Among the most useful general examinations of the early semiconductor industry are Ernest Braun and Stuart Macdonald, Revolution in Miniature: The History and Impact of Semiconductor Electronics (Cambridge, U.K., 1978); Richard Levin, "The Semiconductor Industry," in Richard R. Nelson, ed., Government and Technical Progress: A Cross-Industry Analysis (New York, 1982), 9-100; and Philip Seidenberg, "From Germanium to Silicon: A History of Change in the Technology of the Semiconductors," in Goldstein and Aspray, eds., Facets: New Perspectives on the History of Semiconductors, 35-74.

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10Most of the authors listed above, with the exception of Seidenberg (who points to forces within firms and research tabs as driving change in the industry), would say Department of Defense support has been a significant source of technological innovation in the industry, particularly in its infancy. The government bought 100 percent of all integrated circuits produced in 1962, for example. By 1965, the government's share had dropped to 72 percent, and by 1968, it was a mere 37 percent of the year's total shipment of integrated circuits. Levin, "The Semiconductor Industry," 63. For more on the role of the military in technically advanced industries, see Mowery and Nelson, "Explaining Industrial Leadership," in Mowery and Nelson, Sources of Industrial Leadership; Merritt Roe Smith, ed., Military Enterprise and Technological Change: Perspectives on the American Experience (Boston, 1985).
11Christophe Lecuyer, "Fairchild Semiconductor and Its Influence," in Lee et al., The Silicon Valley Edge, 158.

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12See Joseph A. Schumpeter, The Theory of Economic Development (New York, 1961 [originally published 1911]), especially ch. 2. See also Thomas K. McCraw, "Schumpeter Ascending," American Scholar 60 (Summer 1991): 371-92.
13I am reminded of an observation made by Harold Livesay in the pages of this journal in 1989. Business history's overriding attention to bureaucracy and organizational synthesis, wrote Livesay, "has in recent years, acted much like a neutron bomb, wiping out the people while leaving the buildings intact." Harold C. Livesay, "Entrepreneurial Dominance in Businesses Large and Small, Past and Present," Business History Review, 63 (Spring 1989): 5.

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14Individual entrepreneurs working in Silicon Valley at the end of the twentieth century have recently begun to receive some recognition from scholars. See, for example, Chong-Moon Lee, "Four Styles of Valley Entrepreneurship," in Lee et -al., The Silicon Valley Edge, 94-123.
15In addition to other cited sources, the author's interview ,ath Jim Gibbons (2 June 1999), Gordon Moore (30 March 1999), Harry Sello (25 Jan. 1999), and two anonymous Fairchild founders informed this paragraph. Good discussions of Shockley Transistor Labs can be found in Lecuyer, "Fairchild Semiconductor," in Bassett, "New Organizations," and in Michael Riordan and Lillian Hoddeson, Crystal Fire: The Birth of the Infonnation Age (New York, 1997).

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16Germanium was the preferred semiconductor substrate at the time Shockley began his company. Silicon's higher melting point made it harder to work with than germanium, but silicon (the basic ingredient in sand) is far more abundant, and devices made from it were more reliable than germanium devices. Riordan and Hoddeson, Crystal Fire, 207-8, 221. In the diffusion process, a semiconductor is cooked in a furnace containing appropriate impurities that then seep into the semiconductor in much the same way that hickory flavor seeps into meat cooked in a barbecue pit. Barbecue analogy from T R. Reid, The Chip (New York, 1985), 73-4.

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17For more on "Hot Minds," see Crystal Fire; "Secrets of the Mind," Newsweek, 6 Dec. 1954, 72. Shockley's work on empirical measures for intelligence later caused him problems, when he used his results to argue that blacks were intellectually inferior to

whites.
18For example, he briefly barred Jean Hoerni, a brilliant experimentalist, from lab work and assigned him instead to do the "dog work" of calculating diffusion curves in an apartment Shockley had rented for him not far from the lab. Shockley also believed in public firings; he would gather the group and tell one unsuspecting man to clear out his desk-with no advance warning. Fairchild Founder A, interview by author, 27 Jan. 2000. (A handful of the more than two dozen people I interviewed requested anonymity.)

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19On the shifts from research to product development: Jim Gibbons, interview by author, 2 June 1999; Fairchild Founder B, interview by author, 19 March 1999; Fairchild Founder A, interview by author, 27 Jan. 2000. A diode functions much like a dam or a door, opening at times to let current pass and firmly impeding the flow of current at other times. (A circuit designer determines the conditions under which the diode allows current to pass.) Shortly after Shockley was awarded the Nobel Prize for Physics in November 1956, he began work to build a diode with four layers that would be diffused P-N-P-N. "Inventor Cites Use in Computer," Electronic News, 24 Feb. 1958, 1. For more on the four-layer diode, see Riordan and Hoddeson, Crystal Fire, 267-8.

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20Gordon Moore recalls that he and Noyce wrote a letter to Shockley making these points. Gordon Moore, interview by author, 30 March 1999. 1 have not found the letter in Shockley's voluminous collection in the Stanford Special Collections. For more on these manufacturing difficulties with the four-layer diode, see Riordan and Hoddeson, Crystal Fire, 267. For more on the limited customer base for the product, see Bassett, "New Technology."
21Says Harry Sello, who left Shockley for Fairchild Semiconductor six months after Noyce did: "They could have done that [built the silicon transistor] as easy as falling off a log at Shockley Laboratories if the old man would only have taken the lid off." Harry Sello, interview by author, 25 Jan. 1999. Lecuyer writes that the group had managed to build experimental mesa transistors at Shockley, Lecuyer, "Making Silicon Valley" 154.

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22The story of the contact between the group of seven and Hayden, Stone has been recounted in almost every source listed in footnote 3, though at times it is mistold to include Noyce as one of the original dissidents. Good recountings are by Riordan and Hoddeson, Crystal Fire, and Lecuyer, "Making Silicon Valley" and "Fairchild Semiconductor." The full text of the letter can be found in -The Founding Documents," Forbes ASAP, 29 May 2000, unpaginated.

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23Arthur Rock, interview by author, 23 Feb. 1999.
24Gordon Moore: "We got together for an evening and they say [sic], `Hey, you don't want to find a company to hire you. What you want to do is set up your own company." Our own company, yeah, OK. That way we won't even have to move. So that was the entrepreneurial spirit that drove the formation of Fairchild." Gordon Moore, interview by Alan Chen, 9 July 1992. Intel Archives.
25Fairchild Founder A, interview by Christophe Lecuyer on 6 July 1996. Personal communication from Lecuyer to author, 11 Nov. 1999.

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26Gordon Moore, interview by author, 30 March 1999.
27Entry dated 5 June 1957, Empire Notebook, Shockley Papers, Stanford Special Collections (henceforth SSC).
28Michael F. Wolff, "The Genesis of the Integrated Circuit: How a Pair of U.S. Innovators Brought Into Reality a Concept that was on the Minds of Many," IEEE Spectrum, Aug. 1976, 49. Various versions of this story exist, including an official straw poll, but Wolff writes that Noyce confirmed this version of the story, albeit "with some embarrassment."

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29Entry labeled 6 Jun; entry labeled "Impressions from AOB [Arnold 0. Beckman], call Thurs PM 6 Jun," Empire Notebook, Shockley Papers, SSC. Shockley's notes from the period of most intense turmoil in the company appear in a spiral-bound "Empire" brand notebook dated 23 May-10 June 1957, on the front of which he has scrawled, as if to remind himself: "Try to work it out for the benefit of everyone." "Like you did at meeting, listening."
30Shockley recorded few conversations with any other lab employees at this time, with the exception of Smoot Horsley, who ran the four-layer diode operation and was not part of the disaffected group. Empire Notebook, Shockley Papers, SSC.

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31Gordon Moore, interview by author 30 March 1999.
32Arthur Rock, interview by author, 23 Feb. 1999.
33Fairchild Founder A, interview by Christophe Lecuyer on 6 July 1996.
34 Fairchild Founder A, interview by author, 27 Jan. 2000.
35 Statistics are for Oct. 1956-Oct. 1957. "1958: Everybody's Doin' It," and "The Transis

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for Emerges," Electronic News 25th Anniversary Issue, 25 Jan. 1982 (sect. 2), 6, 23. See also, Alfred Cook and Bob Shephard, "Heavy Commercial Push Top Feature at Wescon," Electronic News, 26 Aug. 1957, 1.

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36 Arthur Rock, interview by author, 23 Feb. 1999.

37 Gordon Moore, interviewed by Alan Chen, 6 Jan. 1993, transcript. Intel archives.
38 "Multifarious Sherman Fairchild," Fortune, May 1960, 170; "Sherman Fairchild-Man of Few Miscalculations," Electronic News, 13 Sept. 1965, 8.
39 "Multifarious Sherman Fairchild," Fortune, 170.

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40 Sources for Fairchild statistics ca. 1957 are Fairchild Camera and Instrument Annual Report 1957; "Man in a Hurry," Forbes, 15 Nov. 1959, 37; and "Fairchild Camera-Portrait of a Growth Company," Financial World 118, 12 Sept. 1962, 10-11.
41Rough Road to Growth," Forbes, 15 June 1965, 30.
42In industries such as automobile manufacturing, oil refining, and tobacco production, many automated operations and testing functions either already used semiconductors or were investigating how to do so. Ken Stein, "Experience in Field is Opening Markets," Electronic News, 17 Feb. 1958, 1.
43Fairchild Camera and Instrument Annual Report 1957. In Noyce's words, Fairchild management was "primed and eager to go along if [the Shockley defectors'] ideas seemed practical." "Fairchild Semiconductor Corporation: Company Profile," Solid State Journal, Sept./Oct. 1960, 1.

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44 Richard Hodgson, interview by author, 19 May 1999.
45 Fairchild Founder B, interview by author, 19 March 1999.
46 Contract between "the California Group" and "Fairchild Controls," 19 Sept. 1957, Shockley Papers, SSC. How Shockley got a copy of the contract is a mystery.
47 Gordon Moore, interview by author, 30 March 1999.

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48Shockley Labs had been one of the few firms in the country working in silicon at the time the eight defectors decided to build silicon transistors. Even Bell Labs, a hotbed of silicon research in the late-1950s, nonetheless built almost all of its transistors from germanium. Philip Seidenberg, "From Germanium to Silicon," 37.
49Letter from L. N. Duryea to Eirckson, Wright, Hanafin, and Steinmeyer, 28 May 1959, Shockley Papers, SSC.
50Of course, corporate genealogy is not destiny, and Semiconductor, descent from Shockley did not guarantee success. Witness, for example, the less-than-auspicious career of Knapic Electro-Physics, a company founded by Shockley employee Dean Knapic a few months after the Fairchild Semiconductor team defected. Daily Palo Alto Times, 18 Dec. 1957. See also, "Transamerica Plan Gets FRB Approval," San Francisco Chronicle, 18 Dec. 1957.
51Certificate of Winding Up and Dissolution, 18 April 1960, Shockley Papers, SSC.

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52There were seven voting trustees: Carter, Hodgson, and two other Camera and Instrument senior managers; Bud Coyle from Hayden, Stone; and Noyce and Eugene Kleiner.
53Contract between "the California Group" and "Fairchild Controls," 19 Sept. 1957, Shockley Papers, SSC. See also letter from Bob Noyce to employees, "Fairchild Semiconductor, 1957-1977" (booklet of reproduced items pertaining to the first twenty years of Fairchild Semiconductor's existence), SSC. Semiconductor's finances were kept entirely separate from those of Camera and Instrument, resulting in nice accounting benefits for the parent firm. Rather than spending the 81.4 million itself-and taking a $1.4 million hit against earningsCamera and Instrument could account for the expenditures piecemeal, so that, for example,

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less than $400,000 of Semiconductor-related expenses were filed against earnings in 1958. This fancy footwork translated to an 80-cents-per-share savings to Camera and Instrument shareholders. Fairchild Camera and Instrument Annual Report 1958.
54Richard Hodgson to Bob Noyce, 2 Oct. 1957, SSC; Richard Hodgson, interview by author, 19 May 1999.
55This creation of a new type of organization, by combining in a new way resources available to others, is, of course, the essence of Schumpeter's definition of entrepreneurship.
56"8 Leave Shockley to Form Coast Semiconductor Firm," Electronic News, 20 Oct. 1957.

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57Richard Hodgson, interview by author.
58Jim Gibbons, Gordon Moore, Harry Sello, and Richard Hodgson commented that Noyce did nothing deliberate to attract attention to himself. Nonetheless, Sello, who worked with Noyce at both Shockley and Fairchild, told a revealing story of Noyce's guest appearance on a public-access television show Sello hosted, called "This Week in Science." In the course of the appearance, Sello says, Noyce "stepped in front of me. And I'm the damn lead on the show. He cut my lines. He upstaged me all over the place.... I made a crack about, `Do you see why he's president of the organization and I'm not?' He burst out laughing." Harry Sello, interview by author, 25 Jan. 1999.

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59Paul Hwoschinsky, interview by author, 25 March 1999. The best discussion of charisma in economic organizations is Max Weber, "The Sociology of Charismatic Authority," in H. H. Gerth and C. W Mills, translators and eds., From Max Weber: Essays in Sociology (New York, 1946).
60Fairchild Founder A, interview by author, 27 Jan. 2000.

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61See, for example, Gordon Moore's discussion of Noyce's suggestion to use nickel plating in an attempt to keep transistor junctions from leaking. Gordon Moore, interviewed by Alan Chen, 6 Jan. 1993, transcript, Intel archives.

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62Hoerni, quoted in Bob Ristelhueber, "Noyce Remembered: Unusual Ideas, Unusual Approaches," Electronic News, 11 June 1990, 4. While at Fairchild, Hoerni developed the planar process, which made batch production of semiconductors possible, The planar process also was the foundation for Noyce's conception of the integrated circuit, which combined in a single device all the components needed to perform an electronic function.

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63One measure of the importance of the integrated circuit is the award of the 2000 Nobel Prize in Physics to Texas Instrument's Jack Kilby, who is generally acknowledged to be the "coinventor," with Noyce, of the integrated circuit. It is safe to say that if the prize were awarded posthumously, Noyce would have shared it. "Jack S. Kilby and Robert Noyce are both considered as the inventors of the integrated circuit," reads the Nobel announcement of Kilby's award. http://nobel.sdsc.eda/announcement/2000/phlinfoen.html (accessed 1 Dec. 2000). Noyce's integrated circuit patent is #2981877; Kilby's is #3138743; Interference #92,541; Case 416 F2d 1391 (1969).
64In May 1959, the eight founders agreed that Noyce, originally head of Research and Development, should serve as general manager after Ed Baldwin, the firm's first general manager, announced that he and eight senior operations people (including five engineers) were decamping to form a rival semiconductor operation. R. Dale Painter, "Seek to Settle Suit on Rheem Semiconductor," Electronic News, 14 March 1960, 12.
65Gordon Moore, interview by author, 30 March 1999.

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66The math is roughly as follows. If only half of the transistors on a given wafer are good, then putting together any two transistors yields chances of only one in four that the combination works; in the case of four transistors, only one-sixteenth are good. There was talk that with twenty or thirty transistors in a given circuit, yields would be so low that each functional circuit would have to cost a fortune. (Even a best-case scenario of 90 percent of transistors actually working resulted in 12 percent overall yields of 20-transistor circuits.) For more on this point, see Robert Noyce, "Machine that Changed the World," Intel Archives; Kilby, "Invention of the Integrated Circuit," 652.

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67The market Noyce and Moore had anticipated took longer to develop than either had predicted. Ultimately, the company felt compelled to introduce a series of drastic price cuts that made it cheaper for a customer to buy an integrated circuit than to buy the individual components and connect them himself. This pricing scheme should be understood as an important element in the "invention- of the integrated circuit: in the language of the history of technology, cost was an essential factor in the "social construction" of the integrated circuit. For a good introduction to social constructivist theories that technologies are not autonomous technical developments, but rather a product of a variety of political, economic, and social influences, see Thomas Hughes, Wiebe E. Bijker, and Trevor J. Pinch, The Social Construction of Technological Systems (Cambridge, Mass., 1987); David Hounshell, From the American System to Mass Production, 1800-1932: The Development of Manufacturing Technology in the United States (Baltimore, 1984); and Donald A. MacKenzie, Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance (Cambridge, Mass., 1990). An interesting

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(and somewhat parallel) discussion of "technological trajectories" and the ways that a certain technological approach becomes the "dominant design" is by Richard R. Nelson, "The CoEvolution of Technology, Industrial Structure, and Supporting Institutions," in Giovanni Dosi, David J. Teece, and Josef Chytry, eds., Technology, Organization, and Competitiveness: Perspectives on Industrial and Corporate Change (New York, 1998), 319-35. For an interesting case within the semiconductor industry, see William Aspray, "The Social Construction of the Microprocessor: A Japanese and American Story," in Facets: New Perspectives on the History of Semiconductors, 215-67.

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68Wolff, "The Genesis of the Integrated Circuit," 53.
69Arthur Rock to partners of Hayden, Stone, and Co., reprinted in "The Founding Documents."
70"Multifarious Sherman Fairchild," 171. The Western Union telegram notifying Fairchild Semiconductor of the buyout is reproduced in "Fairchild Semiconductor, 1957-1977," SSC.

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71Fairchild Camera and Instrument Annual Report 1959.
72Fairchild Camera and Instrument Annual Report 1960, 1961. "Strong Position of Firm Cited by Fairchild Semiconductor VP," Electronic News, 20 March 1961, 16.
73Fairchild Camera and Instrument Annual Report 1961.
74Fairchild Camera and Instrument Annual Report 1962.

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75The stock rose faster than any other on the New York Stock Exchange. "What Made a High Flier Take Off at Top Speed," Business Week, Oct. 1965, 118-20; "Exchange Calls FC&I Pacer," Electronic News, 7 Feb. 1966.
76The patents in question covered a method of building integrated circuits using the planar process. For more on the importance of

licensing and cross-licensing in the semiconductor industry, see Langlois and Steinmueller, "The Evolution of Competitive Advantage in the Worldwide Semiconductor Industry," 19-78.
77Braun and Macdonald, Revolution in Miniature, 78.
78The difficulties of transferring technologies within organizations are unfortunately familiar to many industries. See, for example, Margaret B. W Graham, The Business of Research: RCA

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and the VideoDisc (Cambridge, U.K., 1986). Nonetheless, the "black magic" problems (detailed below) faced by the semiconductor industry were such highly specialized variations on this common theme that I consider them an issue specific to the semiconductor industry.
79We now know that many of these problems had to do with contamination. The Technical and Progress Reports in the SSC are full of examples of the problems entailed in moving from development to manufacturing. To take just one: "The 1210 is behaving in the normal fashion for any device with drastically increased production. The first groups of runs were lost because of a too high base predep [predeposition] temperature. This has been tracked down and corrected, but because of the time lag between base predep and emitter diffusion, close to two weeks work was lost. A problem that has come up since then is the presence of a large percentage of soft units in one run. This has been very uncommon in the 1210. . . ." The writer later says that several problems stem from the "transition to Mt. View," where Semiconductor's manufacturing facilities were housed. "Progress Report-Transistor Development Section, 1 Jan. 1961," Box 5, File 9, Fairchild Research and Development Division, Technical Reports and Progress Reports, M1055, SSC.

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80"Letter from Moore and Grinich to Noyce, 8 Feb. 1961," Box 5, File 11, Fairchild Research and Development Division, Technical Reports and Progress Reports, M 1055, SSC.
81"Trimmed oxide now helps, even though a year ago it did not." "R&D Progress Report from Moore and Grinich to Noyce, 11 Aug. 1961," Box 6, File 7, Fairchild Research and Development Division, Technical Reports and Progress Reports, M1055, SSC.
82"Letter from Moore and Grinich to Noyce, 8 Feb. 1961," Box 5, File 11, Fairchild Research and Development Division, Technical Reports and Progress Reports, M1055, SSC.
83"R&D Progress Report from Moore and Grinich to Noyce, 11 April 1961," Box 6, File 3, Fairchild Research and Development Division, Technical Reports and Progress Reports, M1055, SSC.

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84See, for example, "Letter from Eugene Kleiner to Gordon Moore, I Dec. 1960," Box 5, File 5, Fairchild Research and Development Division, Technical Reports and Progress Reports, M1055, SSC. In this letter, Kleiner explained that staff in Palo Alto were accusing people from Mountain View of taking Palo Alto's supplies of paper and pencils.

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85"R&D Progress Report from Moore and Grinich to Noyce, 11 April 1961," Box 6, File 3, Fairchild Research and Development Division, Technical Reports and Progress Reports, M1055, SSC.
86The spin-off phenomenon was particularly pronounced between 1961 and 1963, and again in the period from 1968 to 1969. Similar forces drove both generations of startup companies. In particular, each generation was founded around the promise of a specific technology-in the early 1960s, the planar process and integrated circuit; in the second wave, largescale integration (LSI) techniques.

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87Jerome Kraus, "An Economic Study of the U.S. Semiconductor Industry" (unpublished New School for Social Research diss., 1973), 110. In 1958 and 1959, electronics stocks rose roughly three times as fast as the Dow Jones industrial average: 50 percent vs. 38 percent in 1959; 60 percent vs. 30 percent in 1958. Stuart Gellman, "Industry Still Flying High in the Market," Electronic News, 28 Dec. 1959, 1. See also, "Transitron Offer Sparks Broker Deluge," Electronic News 25th Anniversary Edition, 25 Jan. 1982 (sect. 2), 28. Alfred D. Cook, "Letter from the Editor," Electronic News, 15 Feb. 1960, 2.
88Kraus, "An Economic Study of the U.S. Semiconductor Industry."

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89Interesting contemporary commentary on the phenomenon can be found in "ExEmploye[e]s File $700,000 Counter Claim," Electronic News, 30 Jan. 1961; "Silicon Transistor Sues Ex-Employe[e]s, Seeks $1 Million," Electronic News, 23 Jan. 1961; "Diotran Pacific Formed by Four In Palo Alto, Cal," Electronic News, 6 March 1961; "Melapar Sues Scope, Others for $500,000," Electronic News, 27 July 1961, 1. See also reports on Computer Dynamics Corp., a Maryland firm which grew from 5 to 100 in the space of a year: "5 Man Firm Grows to 100 in First Year," Electronic News, 7 Jan. 1963, 49. Estimate of the number of new firms is from "The Semiconductor Industry: Mayhem and Millionaires," Electronic News, 25 Jan. 1982 (sect. 2), 16.

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90Fairchild Founder B, interview by author, 19 March 1999; Charlie Sporck, interview by author, 16 Feb. 1999; Fairchild Camera and Instrument Annual Report 1959. At year's end, 52,250 shares that had been authorized for issue under the stock option plan had not been issued. Fully 26,000 of these shares had been authorized during the year 1959.
91Richard Hodgson, interview by author, 19 May 1999. Stock options had gained popularity in the 1950s, when firms began granting them to members of the management team. By the end of that decade, analysts were arguing that technical and scientific men, not just managers, should receive options, and by the early 1960s, leading scientists in the electronics industry expected some form of stock option as part of their compensation package. "You can't get anyone today," one electronics-firm manager complained to Business Week, "unless you can offer him a stock option." "Business Week Reports on Semiconductors," Business Week, 26 March

1960, 110; R. W. Johnson, "Stock Options-Their Place in Engineering Management," Western Electronic News, May 1957, 8.
92Charlie Sporck, interview by author, 16 Feb. 1999.

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93Gordon Moore has called Noyce "a man of many ideas, some of them good" and has said that Noyce never solved problems in a straightforward, systematic way. Gordon Moore, interview by author, 30 March 1999.
94Harry Sello, interview by author, 25 Jan. 1999.
95Richard Steinheimer (graphic artist), interview by Rob Walker, SSC, 25 May 1999.
96Richard Levin, "The Semiconductor Industry," 54. By Levin's estimate, Semiconductor

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labs produced 21 percent of the device structure innovations, 18 percent of new product innovations, and 12 percent of new process innovations. Levin estimates that 10 percent of the major innovations during the discrete device era, 1950-1960, can be traced to Fairchild Semiconductor-an impressive showing, given that Fairchild did not enter the business until the end of 1957.
97Frank Wanlass quoted in George Rostky, "The 30th Anniversary of the Integrated Circuit: Thirty Who Made a Difference," 1988. SSC; Bassett, "New Technology," 99-100.

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98See Lecuyer, "Making Silicon Valley," 176-7. A representative advertisement appears in "A Briefing on Integrated Circuits," television show broadcast in October 1967, courtesy of Harry Sello.
99Walter Matthews, "Shift Semicon Sales Setup at Fairchild," Electronic News, 6 April 1964 1.

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100"A Briefing on Integrated Circuits," television show broadcast in October 1967, courtesy Harry Sello. "Fairchild 'Special' Aimed at Select Group," Broadcasting, 2 Oct. 1967, 35. The article calls the special "a landmark event in television the first of its kind in TV, history." The Fairchild annual report for 1967 notes that the show was carried by 32 stations and "viewed by an estimated 2 million persons. This is [the] first known use of commercial TV to teach a technical subject."

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101"Fairchild Starts Hong Kong Venture," Electronic News, 8 April 1963, 6; Walter Mathews, "Hong Kong Semicon Plant for Fairchild," Electronic News, 17 June 1963, 34. Charlie Sporck, interview by author, 16 Feb. 1999.
102Charlie Sporck, interview by author, 16 Feb. 1999; Lecuyer, "Making Silicon Valley," 244. Many of the sources mentioned in footnote 9 address the issue of automation in the semiconductor industry.
103Other firms included Continental Device Corp., General Electric, and ITT Semiconductor. Don Hoefler, "Hit 'Em Where They Ain't," Electronic News, 15 Jan. 1968, 1.

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104"Man Behind the News," Electronic News, 3 Dec. 1962.
105Noyce, interviewed by Herbert Kleiman, SSC. Some scholars have argued that military work was essential to the development of a culture of continuous innovation in the electronics industry. The military often was more interested in funding the development of state-of-the-art prototype devices (each of which required a great deal of research and development work) than in buying mass quantities of less advanced technology. The theory posits that the existence of a deep-pocketed customer interested in funding innovation after innovation generated a business culture focused on R&D rather than manufacturing. The irony here, of course, is that the innovation-over-manufacturing culture could well describe Fairchild, which nonetheless had very little to do with direct government work. For an introduction to these arguments, see Ann Markusen, Peter Hall, Scott Campbell, and Sabina Deitrick, The Rise of the Gunbelt: The Military Remapping of Industrial America (New York, 1991).

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106Noyce, interview by Kleiman. In their interviews with the author, Charlie Sporck and Gordon Moore confirmed the distaste for direct government contracts at Semiconductor.
107In early 1963, for instance, Moore estimated that while government contracts represented "only about 5070 of our total laboratory effort [in 1962], they have given us invaluable experience." "Research and Development Progress Report of 1962, 24 Jan. 1963," Box 7, File 6, Fairchild Research and Development Division, Technical Reports and Progress Reports, M1055, SSC.
108Harry Sello recalls that at Semiconductor, "We carefully chose [government projects] so that the government needed the product and it was work that we needed also in order to promote the commercial aspects of the product." Harry Sello, interview by author, 25 Jan. 1999.
109Fairchild Camera and Instrument Annual Report 1960.

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110Lecuyer, "Making Silicon Valley," chs. 3 and 4.
111Charlie Sporck, interview by author, 16 Feb. 1999. See also Lecuyer, "Making Silicon Valley," 177-95. Lecuyer points out that a contract from Autonetics required the company to "reinforce [its] manufacturing discipline ... document [its] manufacturing processes ... [and] build high-reliability lines using [specific production] techniques" (189).
112See Charlie Sporck, interview by author, 16 Feb. 1999.

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113Lecuyer, "Making Silicon Valley," 239. See 237-47 for a good general discussion.
114"You'd think these two men [Bay and Sporck] were going to fight each other on the floor," Richard Hodgson recalls, adding that Noyce would usually just sit back and let the arguments run their course. Richard Hodgson, interview by author, 19 May 1999.

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115To take but one example of volume production: in 1965, integrated circuits of a sort called complementary-transistor logic (CTL) were shipped in quantities of a half-million units or more. Fairchild Camera and Instrument Annual Report 1965.
116Charlie Sporck, interview by author, 28 Dec. 2000.

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117 For quite a while, Semiconductor had built its own test equipment. The instrumentation division was formed to commercialize this equipment, and it also incorporated resources from Dumont Laboratories, an early Fairchild acquisition that had been plagued with troubles for years. Fairchild Camera and Instrument Annual Report 1965; Don Hoefler, "Shakeup in Sunnyvale," Electronic News, 16 Feb. 1970.
118Fairchild Camera and Instrument Annual Report 1965, 1966. In 1965, Fairchild Camera and Instrument had 11,545 employees; in 1966, the employee base was 13,591.
119 Fairchild Camera and Instrument Annual Report 1966. The company had roughly 2.6 million shares outstanding.

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120James Lydon, "Recruiting Fever Mounts in Microelectronics Field," Electronic News, 25 July 1966, 1.
121For an excellent discussion of tensions between Semiconductor's Palo Alto and Mountain View facilities in the late 1960s, particularly in connection with MOS developments, see Bassett, "New Technology," 256-70.
122"R&D Progress Report from Moore and Grinich to Noyce, 11 June 1962," SSC.
123Bassett, "New Technology,- 208. Bassett's dissertation focuses on the development of MOS technology at Fairchild Semiconductor and elsewhere.

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124For example, in February 1963, Semiconductor announced it would soon bring to market an MOS transistor, only three weeks later to issue a statement that "Fairchild Semicondoctor's field-effect metal-oxide semiconductor transistors are still in the laboratory and are not for sale. [The company] does not know when they will be released from the laboratory. . . ." Walt Bohne, "New Fairchild Transistor Seen at 1/3 Usual Cost," Electronic News, :3 Feb. 1964, 32; "Fairchild Field Effect Transistors Still in Lab," Electronic News, 26 Feb. 1964, 37.
125"Dr. Noyce candidly admitted that Fairchild's history with the metal-oxide-silicon technology has been rather erratic. While the company got into it early under the impetus of Frank Wanlass, when he departed for General Micro-Electronics, and later general Instrument Corp., Fairchild's MOS effort became spotty." Don Hoefler, "FC&I, Mountain View, Breathes Easier," Electronic News, 30 Oct. 1967. For an excellent discussion of MOS at Fairchild Semiconductor, see Bassett, "New Technology," chs. 4 and 5.

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126Charlie Sporck, interview by author, 28 Dec. 2000.
127Don Hoefler, "FC&I Profit Dip on ICs," Electronic News, 21 Nov. 1966, 12.
128Hoefler, "FC&I Profit Dip on ICs"; Walter Matthews, "Geographic Expansion Set by Fairchild," Electronic News, 19 July 1965.
129Roger Borovoy, interview by author, 27 Jan. 1999.
130Hoefler, "FC&I Profit Dip on ICs," 12. Camera and Instrument never broke down earnings by division, so it is impossible to determine the exact impact of the troubles at Semiconductor on the division's bottom line.
131Fairchild Camera and Instrument Annual Report 1966.

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132Robert Noyce to Sherman Fairchild, 25 June 1968. Camera and Instrument (lid not break down earnings by division, but Time estimated that Semiconductor was responsible for 98 percent of the parent company's profits. "Mighty Miniatures," Time, 4 March 1965, 93-4.
133 Fairchild Camera and Instrument Annual Report 1966.
134"What Made a High Flier Take Off at Top Speed," 118-22.
135"Semiconductor Moving, Realigning Top Management," Electronic News, 6

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March 1967, 54. Among those who left with Sporck, or shortly thereafter to join him, were Floyd Kvamme, marketing manager for ICs; Pierre Lamond, IC production manager; Roger Smaller, manufacturing manager for ICs, Fred Bialek, overseas operations manager for microcircuits; and Don Valentine, director of marketing.
136Hoefler, "FC&I Profit Dip on ICs."
137Charlie Sporck, interview by author, 16 Feb. 1999. "Ibid.

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139"I suppose I essentially cried when he left," Noyce told a reporter. "Working with people that you're fond of, then having them break apart, was I would almost say devastating." Malone, Big Score, 108.
140Gordon Moore, in an interview with the author, recalls that Noyce first offered the job to him. Bay laid off 150 people at the Mountain View manufacturing facility and granted marketing a great deal of power over key decisions, such as what products to make, and when. For example, Jerry Sanders, the new marketing manager, spearheaded the introduction of a new product every

week for all of 1968. "The Fight That Fairchild Won," 106; "Fairchild

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Semicon Lays off 150 at Coast Plant," Electronic News, 22 Jan. 1968, 45; "The Semiconductor Industry: Mayhem and Millionaires," 16.
141Robert Noyce, "WGBH- The Machine That Changed the World,"' Tape F7, 6-7, Interview Transcript, Intel Archives. In an interview with the author, Sporck recalled that Noyce never even bothered trying to talk him out of leaving. Charlie Sporck, interview by author, 16 Feb. 1999.

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142"Turning a Science into an Industry," IEEE Spectrum, Jan. 1966, 101.
143This figure takes into account a three-for-two stock split during 1967. The additional shares followed on the granting of 215,525 new options-an enormous increase (even taking into account the stock split) over the previous year's 73,400, and the 1965 grant of 5,300. Fairchild Camera and Instrument Annual Report 1965, 1966, 1967.
144Richard Hodgson, interview by author, 19 May 1999.
145"The Fight That Fairchild Won," 106. See, for example, James Lydon, "Five Leave FC&I Div. For ITT Portugal," Electronic News, 27 March 1967; "2 Leave FC&I, Form Firm," Electronic News, 15 May 1967, 39.
146"The Fight That Fairchild Won," 100.

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147"Coast Firm Unplugs Jam in Output," Electronic News, 20 March 1967, 12.
148See, for example, "Paying the Piper," Forbes, 15 Nov. 1967, 65; "FC&I Head Resigns; Earnings Plummet," Electronic News, 27 Oct. 1967, 2.
149Don Hoefler, "FC&I, Mountain View, Breathes Easier," Electronic News, 30 Oct. 1967.
150"Paying the Piper," 65; "Carter Resigns; Earnings Plummet," Electronic News, 23 Oct. 1967.

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151Alfred D. Cook, "Sherman Fairchild's July 4th Fizzles," Electronic News, 8 July 1968, 1.
152 "Operations [at the semiconductor division] were profitable in 1967, although increasing costs, expansion of operations with resulting production difficulties in certain new devices, and lower prices resulted in narrower margins," Fairchild Camera and Instrument Annual Report 1967.
153Cook, "Sherman Fairchild's July 4th Fizzles," 1.
154Carter attempted to rally a small group of directors to defend his acquisitions strategy when the rest of the board wanted to divest themselves of the losing operations. When Carter's rally failed, he quit before he could be fired. Journalist Don Hoefler claimed that Noyce forced Carter's departure. Hoefler recalls that a few days after Carter left, Noyce

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turned to the reporter and said (with an "intense countenance"), "When you set out to kill the king, you'd better kill him dead." Don C. Hoefler, "Captains Outrageous," California Today, 28 June 1981, 42.
155Charlie Sporck, interview by author; Gordon Moore, interview by author; Roger Borovoy, interview by author.
156Robert Noyce to Sherman Fairchild, 25 June 1968. In author's possession.

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157Gordon Moore, interview by Rob Walker, SSC.
158"Semiconductor was the company," Noyce said, "but they [Camera and Instrument] insisted on treating it as just another division." Don Hoefler, "Dr. Noyce Happy Doing His Thing," Electronic News, 28 Oct. 1968, 1.
159"The Fight That Fairchild Won," 112. This version of events is supported by details in "Musical Chairs," Electronics, 19 July 1968, 45.

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160 Lester Hogan, interview by Rob Walker, SSC, 22 Aug. 1995.
161 Ibid.
162 "Where the Action is in Electronics," Business Week, 4 Oct. 1969, 90; Malone, Big Score, 124.

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163The one exception was marketing VP Tom Connors. "War Drums Start to Beat in Phoenix," Electronic News, 19 Aug. 1968, 12. In two years, some sixty former Motorola employees caught what one wag called "the Motorola-to-Fairchild Express" to California. Stanford Erickson, "How Hogan Rescued Fairchild," International Management, July 1970, 22; Don Hoefler, "Underground Express to California," Electronic News, 9 Sept. 1968, 2.
164"Fairchild Camera Formalizes Base Location to California," Electronic News, 30 Sept. 1968, 70.
165Lester Hogan, interview by Rob Walker, SSC, 22 Aug. 1995.

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166Although Noyce was nominally president and Moore vice president, both men insisted that the power division was equal. Nilo Lindgren, "Building a Rational Two-Headed Monster: The Management Style of Robert Noyce and Gordon Moore," Innovation, n.d., but clearly 1970. Courtesy Regis McKenna.

167Intel Annual Report 1979.
168http://www.intel.com, accessed 28 Jan. 2001.
169In the twenty years following the bombing of Pearl Harbor, over 400,000 new jobs

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were created in Santa Clara County, many at the Peninsula's booming electronics companies. Between 1960 and 1975, while the nation's employment rate grew 46 percent and California's 65 percent, Santa Clara County's increase was 156 percent. Annalee Saxenian, "The Genesis of Silicon Valley," in Peter Hall and Ann Markusen, Silicon Landscapes (Boston, 1985), 2034. By 1965, firms specializing in semiconductor manufacture had supplanted vertically integrated electronics firms as the leading U.S. merchant semiconductor manufacturers. Langlois and Steinmueller, "The Evolution of Competitive Advantage in the Worldwide Semiconductor Industry," 33.
170 Alfred D. Chandler Jr., "The Information Age in Historical Perspective," introduction to Alfred D. Chandler Jr. and James W Cortada, eds., A Nation Transformed by Information: How Information Has Shaped the United States from Colonial Times to the Present (New York, 2000), 31.

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171By the end of Noyce's tenure at Fairchild, one reporter could write that the company "seemed dedicated to technology for its own sake .... At Fairchild, it almost seemed that no engineer wanted to be in production." "Musical Chairs," 45. Erickson, "How Hogan Rescued Fairchild," 22. If, in the words of Raychem CEO Paul Cook, "what separates the winners and losers in innovation is who masters the drudgery," at Semiconductor under Noyce, not enough people took responsibility for the drudgery. William Taylor, "The Business of Innovation: An Interview with Paul Cook," Harvard Business Review (March-April 1990): 97-106.

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172Robert Noyce, interview with Mary Burt Baldwin, Intel Archives. Noyce's situation was far from unique. In a recent Harvard Business Review article, Robert Coffee and Gareth Jones point out that it is unusual for "great leaders" to be "great coaches." More typical, they write, are leaders "whose distinctive strengths lie in their ability to excite others through their vision [rather] than through their coaching talent." Robert Goffee and Gareth Jones, '-Why Should Anyone Be Led By You?" Harvard Business Review (Sept.-Oct. 2000): 63. Howard H. Stevenson and David E. Gumpert make a similar distinction between "promoters" (entrepreneurs) and "trustees" (administrators). Stevenson and Gumpert, "The Heart of Entrepreneurship," Harvard Business Review (March-April 2000): 84-94. A good case study is Charles Cheape, Family Firm to Modern Multinational: Norton Company, a New England Enterprise (Cambridge, Mass., 1985), particularly his discussion of the arrival of the company's first professional manager, Robert Cushman.
173Robert Noyce to Sherman Fairchild, 25 June 1968.

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