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Growing where you are planted: Exogenous firms and the seeding of Silicon Valley

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ABSTRACT

What are the respective roles of indigenous and exogenous factors in the development of high-tech regions? Entrepreneurs and their start-ups have dominated Silicon Valley's economy in recent decades, but a different dynamic was at work from 1940 to 1965, when the Valley emerged as a formidable high-tech region. In key industries (electronics, semiconductors, computers, and aerospace) that defined Silicon Valley as a high-tech cluster during that period, companies based elsewhere played critical roles in planting the organizations that would – through the innovations they made, the technical talent they attracted, and the start-ups they spun off – help make the Valley the world's most admired and emulated high-tech region.

1. Introduction

What are the respective roles of indigenous and exogenous factors in the development of high-tech regions? Several studies suggest that one of the factors driving the success of high-tech regions is entrepreneurship, and a common unit of analysis for such studies is the individual firm (Acs and Armington, 2006; Audretsch et al., 2006; Hart, 2003; Schoonhoven and Romanelli, 2001; Shane, 2005). In Silicon Valley, the proliferation of such high-tech enterprise is striking: the Valley has become the world's foremost incubator of high-tech firms. Estimates from 2002 suggest that the Valley had become home to more than twenty thousand high-tech firms, employing more than a half million workers (Zhang, 2003). So is Silicon Valley simply the end result of a sufficient number of start-ups? My findings suggest that the development of Silicon Valley has been a far more nuanced — and exogenous — story.

The garage-based myth, which explains the development of Silicon Valley through a series of start-ups, is of course grounded in fact. Apple's garage has an important antecedent in Hewlett-Packard's (1938). Before Google staked out a central position on the World Wide Web, Federal Telegraph Company (1909) established an international telecommunications network. Before Intel's colossus of the miniature, William Eitel and Jack McCullough also built a company (1934) that made electronic components (Lécuyer, 2007, p. 32). Yet indigenous start-ups (which I define as those started and headquartered locally), attention-grabbing, colorful, and important as they have been, do not represent the entire story of Silicon Valley's development.

From 1940 to 1965, the area that would become known as Silicon Valley – the northern part of Santa Clara County (Palo Alto, Mountain View, Sunnyvale, Santa Clara, San Jose) and the southern part of San Mateo County (Menlo Park, Redwood City, San Carlos) – emerged as a formidable high-tech region. On the eve of World War II, the region had a number of small indigenous firms, but overall the region's high-tech manufacturing industry employed fewer than 100 engineers and scientists. The region's subsequent growth as a high-tech region was of sufficient magnitude that by the mid-1960s, as the region sped toward its 1970 level of 100,000 high-tech employees, officials from regions ranging from South Carolina to Texas to New Jersey to Colorado were trying to glean the secrets from this high-tech model (Leslie and Kargon, 1996).

Hidden in plain sight during this growth period has been the role played by the Valley's less attention-grabbing, less colorful, but very important species: the local divisions and subsidiaries of firms based elsewhere. As Intel co-founder Gordon Moore notes, "Focus on only new smaller ventures misses the system nature of this kind of regional economy. A key feature of Silicon Valley has been its mix of both small and large high-tech companies." (Moore and Davis, 2004, pp. 33–34) And during this key period in the Valley's development, the large enterprises were primarily branches of multilocational firms.

Using analysis of qualitative and quantitative information, this article will show that during the period ending in 1965, in key industries (semiconductors, computers, aerospace, and to a lesser extent, electronics) that helped define the area as a high-tech cluster, distant organizations played critical roles in planting the

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enterprises that would – through the innovations they made, the technical talent they attracted, and the start-ups they spun off – help make the Valley the world's most admired and emulated high-tech region. The strategic intent behind these local operations (especially in the Valley's first movers in semiconductors, computers, and aerospace) came from outside the region—a far cry from the Valley's more indigenous, self-directed culture of the 1980s and 1990s.

Furthermore, in each of the four industries under consideration, a key attraction for the external firms was proximity to Stanford University and, in the case of computers, UC Berkeley. The result, by 1965, was that the scale and scope of high-tech talent in the region had attained "critical mass," which allowed for specialized roles for firms and for individuals. It meant that the region needed to attain a certain scale before it made economic sense for an infrastructure of venture capitalists, lawyers, headhunters, etc. to develop (Kenney and von Burg, 2000: 224; Kenney and Florida, 2000: 115). It meant that, in this crucial node in the knowledge economy, the region's most valuable assets (its high-tech workers) could craft careers by moving from one firm to another while staying in one area, rather than making a series of geographic moves while employed by the same firm. Ironically, the presence of firms such as IBM and Sylvania, which represented the latter model, would help make the former model possible in the Valley.

Audretsch et al. (2006: 20) note: "Much of the innovative activity is less associated with footloose transnational corporations and more associated with high-tech entrepreneurship located in innovative regional clusters such as Silicon Valley, Research Triangle Park, Boston's Route 128, and Austin, Texas." That is certainly true of today's Silicon Valley. Yet based on global research, Bresnahan et al. (2001, p. 835) note that, in general, "economic factors that give rise to the start of a cluster can be very different from those that keep it going." They suggest that "the Silicon Valley of 40 years ago [the 1960s] is also closer to today's nascent clusters than either is to the Silicon Valley of today" (p. 842). The present article investigates a related issue. The Silicon Valley that was visible in the 1980s and 1990s, when most of the scholarly analysis of the region began, was dominated by the activities of indigenous firms. What drove development of Silicon Valley in earlier years?

The idea of setting off on their own and attaining autonomy and a share of the profits from their innovations has inspired generations of entrepreneurs in the Valley. I will show, however, that during the Valley's years of scaling up (1940–1965), many of its key players operated as branch operations under the control of distant companies as opposed to models of indigenous autonomy. I will begin with a review of the literature of Silicon Valley as a high-tech region. I will provide macro data showing the dominance of big business in America during that period, and how the Valley fit the pattern. Then I will examine key industries of electronics, semiconductors, computers, and aerospace, and show that during the Valley's years of scaling up, strategies of organizations based elsewhere helped point the direction the Valley would take, and served to accelerate its growth.

2. High-tech regions and the Silicon Valley model

In recent years, Silicon Valley has inspired a shelf full of books, including

1. Profiles of key individuals, memoirs of participants, and journalistic accounts (Berlin, 2006; Cringely, 1993; Gillmor, 2004; Kaplan, 1999; Lewis, 2000; Malone, 1985, 2007; Packard, 1995; Shurkin, 2006), and
2. Analytical volumes and collected essays on the development of the Valley and the institutions involved (Kenney, 2000; Lécuyer, 2007; Lee et al., 2000; Leslie, 1993; Lowen, 1997; O'Mara, 2005; Rogers and Larsen, 1984; Saxenian, 1996).

Silicon Valley literature has emphasized the start-up. Little wonder: by the time a number of scholars were doing serious research on the region (in the late 1980s and early 1990s), the Valley had become America's premiere high-tech entrepreneurial region. Using contemporary interviews, Saxenian (1996) emphasizes how flexible production networks, permeable interfirm boundaries, and a culture of cooperation encourage innovation and entrepreneurship. Martin Kenney emphasizes the creation of an institutional infrastructure necessary to foster start-ups, a necessary condition for the region's hyper-activity of the 1980s and 1990s (Kenney, 2000; Kenney and von Burg, 2000). Lécuyer (2007) traces the take-off of the region to "technological and entrepreneurial groups" behind the development of key indigenous electronic component firms, culminating in the semiconductor firms that would give the Valley its name.

The nature of regional economic development has led many to ask: To what extent does Silicon Valley approximate an industrial district? In the 1980s there was a revival of interest in the work of Alfred Marshall (1890), which explored the "agglomeration economies" that appear when firms in one industry cluster together. Marshall's ideas were revisited in studies of industrial clusters in Italy, which identified flexible production networks, indigenous enterprise, and a high level of regional self-sufficiency as keys to the development of regional clusters (Piore and Sabel, 1984).

To what extent has Silicon Valley also been self-sufficient? Langlois and Robertson (1995, p. 42) distance the "innovative networks" of Silicon Valley and Route 128 from Marshallian and Italianate districts by virtue of the extent of disruptive innovation involved. In regions like Silicon Valley and Route 128, they distinguish between networks of producers and networks of venture capitalists, where the extent of local control "is frequently reduced to the extent that the venture capitalists come from other regions" (p. 126). Florida and Kenney (1990) take issue with the idea of Silicon Valley's self-sufficiency, as does Gordon (1993), who highlights the Valley's participation in global supply networks. Similarly, Harrison (1994) argues against the self-sufficiency implicit in both the entrepreneurial and the industrial–district models, emphasizing the role of external forces (the federal government and multinational corporations) in the rise and continued growth of Silicon Valley. Leslie (2000) does as well, referring to the federal government's role as a prime "angel" investor during the years when the Valley scaled up. Gray et al. (1998) emphasize the actions of local boosters and government officials in the development of Research Triangle, which they call a "satellite industrial platform" because of its emphasis on branch operations of multilocational firms. They also suggest the applicability of the concept to South Korea and other developing countries (Park and Markusen, 1995). This article will show the extent of the concept's application to the development of Silicon Valley.

Location decisions have turned traditional roles for start-ups and established firms on their heads. Entrepreneurs, upon whom we depend for disruptive technology, have tended to grow where they are planted, as Cooper and Folta (2000), Schoonhoven and Romanelli (2001), and Zhang (2003) show. Studies found that more than 97 percent of new companies in Palo Alto and 90 percent in Austin, Texas, had at least one founder who had already worked within commuting distance of the new firm's location. Cooper (1985) suggests that, at least for high-tech firms, the location decision comes from an established firm that acts as an incubator for start-ups. So established firms, better known for tweaking status quo technology, have made more disruptive location decisions. I will show that during the period when Silicon Valley emerged as

Table 1
Silicon Valley's high-tech workforce, 1961–1980.

Year	Total workforce	Indigenous firms		Satellite branches	
	Number of employees	Number of employees	Percentage of total workforce	Number of employees	Percentage of total workforce
1961	39,647	14,371	36	25,276	64
1970	97,820	31,884	33	65,936	67
1980	114,383	65,129	57	49,254	43

Sources: Dun and Bradstreet (1961, 1970, 1980). *Note*: Categorization of indigenous firms versus satellite branches is based on independent verification of headquarters location of each establishment listed in Dun & Bradstreet directories.

a prominent high-tech region, one of the key factors was location decisions made by executives of firms based outside of the region.

3. The 1940–1965 period: an overview

In 1940, the aerospace, semiconductor, and modern computer industries did not yet exist. Each would become a major source of jobs and innovation in Silicon Valley. In each industry, the seed was planted in the Valley by a distant organization pursuing a strategy decided on by distant executives. For each organization, Stanford University (and in the case of computing, UC Berkeley) acted as a powerful magnet.

Stanford's principal contributions to achieving a critical mass of brains in local industry involved relations with satellite operations of firms headquartered elsewhere more than with local start-ups. In the late 1940s, Stanford was a university with a regional reputation whose administrators entertained ambitions of something far greater. Such ambition required resources, and Stanford was strapped for cash. Stanford pursued two approaches to its resource problem: one was to garner an increased share of government contracts and grants; the other was to pursue resources from industry (Lowen, 1997).

Stanford instituted four formal outreach programs to industry from the mid-1940s to the mid-1950s: Stanford Research Institute (SRI), Stanford Industrial Park, the Honors Cooperative Program, and the Industry Affiliates Program. In all four programs, local start-ups represented a small minority of participants, whereas satellite operations of companies headquartered elsewhere were the principal industrial participants. Each of these programs served primarily to bring money to the university (much of which would be used to expand the faculty), and established firms were more likely than start-ups to have the deep pockets required to participate (Adams, 2005).

During this period, Santa Clara Valley was not the only place where established firms were the ones to watch regarding innovation. In the United States, the 1950s and early 1960s was a period of industrial centralization: start-ups did not play the central role in high-tech they would in subsequent years. By 1962, America's five hundred largest industrial firms controlled two-thirds of manufacturing assets (Blackford, 2003, p. 138; Averitt, 1968; Galambos, 1994). From 1950 to 1972, the number of self-employed non-farm businesspeople declined (Blackford, 2003). It is safe to say that in the 1950s and 1960s, the default mode for American businesspeople was *not* to start their own businesses—which is one of the reasons that start-up activity in Silicon Valley and elsewhere attracted such attention.

Overall, data provided by Dun & Bradstreet (D&B) show that Silicon Valley conformed to this trend rather than bucking it. Beginning in the 1960s, Dun & Bradstreet gathered data (such as number of employees) by town and by SIC code for each U.S. manufacturing plant with twenty or more employees. The available data Dun & Bradstreet published in 1961, 1970, and 1980 for San Mateo and Santa Clara counties include key high-tech industries such as computer equipment, instrumentation, electronic components, aerospace, and communications equipment.

During the 1960s, the majority of scientists and engineers in what would become Silicon Valley worked for branches of companies based elsewhere. As late as 1970, nearly two-thirds of employees in key Valley industries worked for such divisions and subsidiaries (see Table 1).[1]

In the next four sections, the article will examine how in four industries multilocational firms helped seed Silicon Valley. "Electronics" refers to electronic components, principally the makers of vacuum tubes (I acknowledge that many firms — such as Federal Telegraph — straddled other industries). Industries, like companies, have their own spin-offs: "Semiconductors" grew out of electronic components. I have titled the third section "Computers" because its principal player, IBM, was the industry leader, and the operations in the Valley (primarily storage technology during the period under review) were in service of the company's computers. The fourth section, "Aerospace," involves missiles and space systems.

4. Electronics (vacuum tubes)

The Valley's electronics industry had entrepreneurial roots. As Timothy Sturgeon shows, the Valley's earliest activities imprinted features we associate with the Valley of today: industry connections with Stanford University and a cycle of start-up and spin-off (Sturgeon, 2000; Adams, 2003). In the early twentieth century, the San Francisco Bay Area was one of the nation's leading hotbeds of radio enthusiasts (Lécuyer, 2007, pp. 15–16). The Federal Telegraph Company (FTC), established in Palo Alto in 1909, was a pioneer in wireless radio and telegraph transmission, acting as operator, seller of transmission equipment, and then source of vacuum tubes. Funded in part by David Starr Jordan, the president of Stanford University, and C.D. Marx of Stanford's engineering department, at its high-water mark FTC employed dozens of engineers (Aitken, 1985).

The FTC story also featured regional abandonment. FTC became a case study in the risks posed to a region by exogenous control of local industry. During FTC's first two years, the Stanford group lost control of the firm to San Francisco investors (Aitken, 1985). The San Francisco investors sold FTC to ITT in the 1920s, and its manufacturing operations moved to Newark, New Jersey, in 1932 (Sturgeon, 2000). One of the lessons of the FTC story is that although enterprise may be footloose, a research university such as Stanford tends to be solidly anchored and can help sustain a high-tech region in the face of industry abandonment.

Left behind, in addition to Stanford University, were indigenous firms such as Eitel-McCullough, Fisher Research Laboratories, and Litton Engineering Laboratories (whose founder, Charles Litton, had worked for FTC, but chose to remain in the Bay Area after FTC's move to New Jersey). Between the Depression and the departures, however, by 1940, there were fewer than one hundred industry engineers and scientists in the Bay Area, far short of high-tech critical mass the area would later be recognized (Terman, 1973; U.S. Bureau of the Census, 1942, p. 104).

[1] These data, published in Dun & Bradstreet's *Metalworking Directories*, are not cited in any of the major studies of Silicon Valley.

Christophe Lécuyer shows that the period beginning in 1940 was one of real scaling up for indigenous firms such as Eitel-McCullough (which took off during World War II), Litton Industries (which grew as a defense contractor in the late 1940s and early 1950s), and Varian Associates, which was founded in 1948 (Lécuyer, 2007). Yet even in this industry dominated by indigenous activity, external influences played a major role. The Varian saga represents a good example. Although the company was founded in the Valley, its roots were in a relationship that involved East Coast financial and strategic control. In his 1930s attempts to develop local high-tech industry, Stanford electrical engineering professor Frederick Terman had begun to forge ties between electrical engineering and physics. The Stanford physics professor William Hansen and his research associates Sigurd and Russell Varian invented the klystron (a microwave tube with potential military and commercial demand) in 1937. The Varian brothers signed a contract with the university that allowed them access to the laboratory (and faculty members) in exchange for a share of revenues from their inventions (Varian, 1983). In turn, Stanford granted exclusive rights to the klystron to the Sperry Gyroscope Company of New York in exchange for annual royalties of up to $25,000 (Kargon and Leslie, 1994; Varian, 1983).

The arrangement provided what the Varians wanted most: access to lab equipment and sufficient money to run their experiments. Meanwhile, Sperry sought control of the nature and scope of research performed. Even more significant, Sperry exercised its authority to choose the location of the research. In 1940, Sperry closed its West Coast operation and moved the Varians, Hansen, Edward Ginzton, and their lab associates to Long Island, repeating what had happened with FTC less than ten years earlier. Once again, eastbound enterprise included locals who preferred to stay in the Bay Area. Some refused to go east; some went east and then returned. During World War II, Ginzton approached Sperry management with a plan to establish a plant in Palo Alto at which the group would continue its work after the war. Sperry said no, and after the war the group left Sperry to return to Stanford (Lenoir, 1997).

The Varians' second setup at the university did not last long because the only available path to sufficient funding within the university was government-sponsored research, which meant that the government had considerable control over the way in which Stanford researchers worked. The U.S. Office of Naval Research dictated that the role of the physics department would be rather narrow. Furthermore, the sort of wide-ranging research the Varians preferred required a free flow of information, yet their military work would have to be moved off campus in order to limit access to those with security clearances. Therefore, Varian Associates was established as an independent firm in 1948. H. Myrl Stearns, the head of Sperry's microwave tube department, was recruited to be the new firm's CEO (Lécuyer, 2007). In less than ten years, Varian would become the largest high-tech firm based in the Valley (Leslie, 1993).

Varian was only the first of many microwave firms — or microwave divisions of large firms — to locate in the Valley, and the first of many (including General Electric, Admiral, and Zenith) to locate in Stanford Industrial Park. Like other makers of television and radio components, Sylvania sought defense work during the Korean War. In 1953, Sylvania secured a $3 million contract for electronic countermeasures. Sylvania was subject to both Stanford pull and government push: although Sylvania's research center was on Long Island, the company located its new laboratory in Mountain View in response to the Army's concerns about the East Coast's vulnerability to attack. In short order, Sylvania became the first corporate participant in Stanford's Honors Cooperative Program. By the early 1960s, Sylvania's Electronics Defense Laboratory employed 1300 people. The company's impact on the Valley proved even greater owing to its influence on the competition, and because one of its executives, William Perry, founded Electronic Systems Laboratories in 1964 (Leslie, 1993).

When General Electric became one of the first tenants of the Industrial Park in 1954, it had several motivations. First was a combination of technological and market motives: GE wanted "an entry into the vast electronic potential of California." GE was specifically interested in the klystron and traveling-wave tubes and was convinced that working with Stanford in such areas would "have a terrific sales appeal to the military." Indeed, a report from the company's Government Marketing Section noted that "recent tube developments at Stanford University are of such import that a liaison specialist should be assigned on a rotating basis to keep our ECM (electronic counter-measures) systems and components engineers informed." GE had a second motivation: it sought a location near Stanford's Microwave Laboratory because "one of our major competitors (Sylvania) is already participating in such a program" (General Electric Co., 1954, pp. 2–3). GE's contract with Stanford also called for faculty to consult at GE and for GE's staff to teach at Stanford. The financial arrangements were large-scale: $1.3 million from GE to Stanford for the first three years (Lenoir et al., 2004). GE's relationship with Stanford would last for more than three decades (Lenoir, 2004).

So although electronics in the Valley was largely an entrepreneurial story, there were some important exogenous developments. The 1947 invention of the transistor at AT&T's Bell Labs would change the landscape for tube makers. Solid-state developments would result in faster processing capabilities, require less space, and generate less heat. A number of tube producers attempted to make the shift to semiconductors, but the big story in Santa Clara Valley would involve a separate set of firms.

5. Semiconductors

For years, many Silicon Valley offices (and then cubicles) featured a chart that traced the genealogy of the local semiconductor industry (Tilton, 1971, p. 79; Kenney and von Burg, 2000, p. 231). This family tree was a way for subsequent spin-offs to trace their entrepreneurial roots to the founding groups from the 1950s. The chart captured one of the distinctive aspects of the Valley: the continuous cycle of start-up and spin-off. That cycle was so pronounced in the semiconductor industry, and the semiconductor industry would become such an important undergirding of the Valley's other industries (many companies in instrumentation, aerospace, telecommunications, and computers would establish semiconductor divisions), that the story of the Valley has sometimes been conflated with the story of semiconductors.

Steven Klepper shows how semiconductor spin-offs were central to the history of the Valley (Klepper, 2009, pp. 79–80). The industry family tree shows that although spin-off activity began almost immediately in the Valley's semiconductor industry, not until the mid-1960s did it really take off. Whereas the period 1957–1986 brought more than 100 new semiconductor firms to the Valley, as of 1965, the chart shows only eight semiconductor spin-offs (Tilton, 1971, p. 79). Intel, National Semiconductor, and Advanced Micro Devices (AMD) – the organizations that would be the face of the industry for decades – were each founded in the late 1960s, after the period under discussion here.

The genealogical chart draws particular attention to the 1955 founding of Shockley Semiconductor Laboratories and the 1957 founding of Fairchild Semiconductor, as will this section. The first two generations of semiconductor firms in the Valley relied on sources of funding from afar. Funding for both Shockley and Fairchild came with strings attached: the distant investors maintained control of the operations, and provided the strategic intent for the enterprises. The local technology talent at both Shockley and Fairchild harbored grievances against their distant owners. In the case of the first generation (Shockley), the grievance was about power that Shockley's superior, Arnold Beckman, had but did not exercise. In the case of Fairchild Semiconductor, it was about power that Sherman Fairchild's East Coast agents exercised to excess.

William Shockley has been called the "Moses" of Silicon Valley. In launching Shockley Semiconductor Laboratory, he led a talented group of scientist and engineers to what was then called the "Valley of Heart's Delight." Shockley and his group brought with them the silicon technology that later gave the region its name. Members of that group later started successful businesses and made lots of money, but Shockley himself did not—hence the biblical allusion (Riordan and Hoddeson, 1997, p. 275).

Shockley had headed the team at Bell Labs that invented the transistor (Shockley, John Bardeen, and Walter Brattain would win the 1956 Nobel Prize in physics for the breakthrough). Within five years of the transistor invention, Shockley had become frustrated with his career at Bell Labs, where he headed transistor physics research. Shockley wanted to escape middle management, run his own show, and receive the financial reward he thought he deserved (Riordan and Hoddeson, 1997). Indeed, the agreement he signed with Beckman in September 1955 listed among Shockley's objectives "a position of prestige and authority" and "financial reward commensurate with performance [including] some means for obtaining capital gains benefits" (Beckman, 1955).

Shockley would end up in Palo Alto, where he had grown up and where his mother still lived. If Palo Alto was his destination from the beginning, however, he took a very roundabout path to get there. After being passed over for the position of director of research at Bell Labs, Shockley took leaves of absence for stints in academia (Caltech) and government (the Pentagon). He then explored academic positions at Yale, Berkeley, and MIT (Watson, 1955; O'Brien, 1955), as well as industry positions at Raytheon (where he consulted for a month, but failed to land the $1 million, three-year contract he sought) and RCA (Hoefler, 1968; Koontz, 1954). In short, he pursued opportunities in Connecticut, Massachusetts, and New Jersey as well as California.

Perhaps his most promising leads involved the burgeoning aerospace industry in Southern California. During the years 1949–1955, semiconductor divisions of government contractors built up formidable high-tech research and development operations, most notably at Hughes Aircraft, led by Simon Ramo and Dean Woolridge (both Caltech PhDs). Woolridge had been a colleague of Shockley's at Bell Labs prior to World War II (Riordan and Hoddeson, 1997, p. 232). In the early 1950s, Hughes had the largest stable of industry PhDs with the exception of Bell Labs, and was the leading producer of semiconductors (Tilton, 1971, p. 65). In 1953, however, Ramo and Woolridge departed to form the company that would become TRW, and in 1954, Harper North, who had headed transistor efforts at Hughes since 1949, left to join Pacific Semiconductors, Inc. (Barnes, 2003, p. 5). Trying to overcome these key departures, Hughes Aircraft extended an offer to Shockley in June 1954 at the same $30,000 salary he would ultimately accept from Arnold Beckman (Dietrich, 1954). One of the main attractions for Shockley, however, would have been the opportunity to work with PhDs such as Ramo and Woolridge. He even negotiated briefly to join their new firm (Riordan and Hoddeson, 1997, p. 232).

There is a saying in Silicon Valley that when you ask for money, you get advice, and when you ask for advice, you get money. In August 1955, Shockley contacted Arnold Beckman (Shockley's one-time Caltech professor, whose instrumentation company was based in Southern California). Shockley was seeking advice about how to assemble a board of directors for the enterprise he hoped to establish. Beckman, who "became better acquainted" with Shockley at the February 1955 annual banquet of the Los Angeles Chamber of Commerce, quickly recognized Shockley's naïveté regarding business when Shockley revealed plans to include competitors on his board (Shockley, 1956d; Beckman, 1980, pp. 50–51). After days of discussion, Beckman decided to bankroll him (Riordan and Hoddeson, 1997, p. 233).

Shockley's motives have received more attention than Beckman's. Hiring Shockley was a strategic decision for Arnold Beckman, who saw the potential of semiconductor devices to improve his company's products (Thackray and Myers, 2000, p. 240). Said Beckman: "I expect [this new division] to contribute directly to our continuing effort to develop better instrumentation for science and industry" (Beckman Instruments, 1956). He saw this as a move toward vertical integration, and he was not the only one who recognized that possibility. In January 1956, Los Angeles high-tech entrepreneur Leslie Hoffman wrote Beckman with alarm after he learned about the new division Shockley would lead. Hoffman was supplying Beckman with silicon and indicated that he could not promise to continue if Beckman created an in-house competitor (Beckman, 1956). Indeed, one of the tasks for Robert Noyce at Shockley Semiconductor would be to discern the extent of demand by Beckman Instruments for what Shockley would produce. In November 1956, for instance, Noyce noted that Beckman "will be very interested in anything we can provide" (Noyce, 1956).

Beckman established Shockley Semiconductor Laboratories as a division of Beckman Instruments, with Shockley and his group as Beckman's employees.[2] Had Shockley headed one of the scores of semiconductor spin-offs years later (such as Intel or AMD), his investors might have reasonably expected him to provide his own strategic vision for the enterprise: Who would Shockley's customers be? How would the firm compete? Where was the industry headed, and how would Shockley fit? Such has been the stuff of business plans in the Valley for decades. Such questions were deftly handled by Stanford professor Dean Watkins in October 1957, when starting his electronics firm in Stanford Industrial Park (Watkins, 1957). Yet from 1955 to 1957, Shockley was ill prepared to answer such questions—or to provide strategic direction. Instead, Shockley was comfortable ceding that role to his new boss. Shockley described Arnold Beckman as "unique" because he combined "a background of academic training and experience with proven financial and business competence" (Shockley, 1957a).

Shockley's previous business experience had been with the research laboratory of a regulated monopoly. The possibilities at AT&T were circumscribed by the government, so corporate strategy was likely even less a day-to-day concern at Bell Labs than at other research labs. When he began working for Beckman, Shockley had little concept of the big picture in business. In May 1956, when invited to speak to security analysts about the "future of the electronics industry," Shockley demurred. "My role in the electronics business in the past has been that of research scientist and development engineer," he responded. "I lecture easily on these subjects, but find the business side of electronics more difficult to discuss" (Shockley, 1956b).

It made sense that Arnold Beckman would have the power to make the key decisions regarding this new enterprise, including its leadership, its location, and its strategic direction. Although Beckman's preference was to have Shockley locate near Beckman's Fullerton headquarters, when Shockley proposed Palo Alto, Beckman had a good reason to grant his wish. Beckman's company had two operations in the Bay Area: one in Berkeley and one in Palo Alto. One thing Beckman and Shockley agreed on was the value of proximity to Stanford University. Beckman not only provided Shockley with resources to open his laboratory but also had already

[2] Shockley's agreement with Beckman said: "The initial operations will be carried on with the present organizational structure of Beckman" (Beckman, 1955).

leased property at the Stanford Industrial Park, where Shockley's lab would share a building with Beckman's Spinco Division.

In 1982, Richard Levin wrote: "In the 1950s and 1960s, the aggressive development policy of Stanford University together with the strength of the physics and electrical engineering faculties at Stanford and the nearby University of California at Berkeley, was responsible for the location of numerous merchant semiconductor firms in the Santa Clara Valley" (Levin, 1982, p. 47). The extent of Stanford's role in the Valley's earliest semiconductor days has since been debated. Gordon Moore, who worked for Shockley before co-founding Fairchild Semiconductor and then Intel, wrote that it was not Stanford that "brought semiconductors to Santa Clara Valley, and [its] presence was not critical to the Silicon-defining modes of business developed in that industry" (Moore and Davis, 2004, p. 18). Certainly, as Christophe Lécuyer shows, in the semiconductor industry's early days the flow of technological transfer was from the industry to the university (Lécuyer, 2005). Nevertheless, the pull of Stanford University was central to the initial semiconductor entrant in what would become Silicon Valley. Indeed, a year before starting Shockley Semiconductor Laboratories (SSL), Shockley had spoken with Stanford's engineering dean, Frederick Terman, about the university's plans for semiconductors (Terman, 1955).

Stanford would figure prominently in SSL's plans. In the February 1956 press conference at San Francisco's St. Francis Hotel announcing the new venture, the Stanford connection was front and center, receiving as much attention as the original team. "Our location near Stanford will enable us to attract outstanding technical personnel for our group and permit close association with the University," said Shockley. The result would be "profiting in our activities from the scientific stimulus of the University and the educational opportunities for our personnel" (Beckman Instruments, 1956). Even before the public announcement of the enterprise, Shockley and Stanford electrical engineering professor John Linvill discussed SSL and what would become Stanford's Industrial Affiliates program (Linvill, 1955). Linvill also became a consultant to SSL (Shockley, 1956a). Shockley signed an agreement for SSL to join Stanford's Honors Cooperative Program, which would offer his employees opportunities for graduate education at Stanford (Horsley, 1956; Shockley, 1956c). Terman also signed Shockley on as a lecturer in engineering (Terman, 1956a).

That was just the beginning of the Stanford University relationship. Beckman signed a lease to grant SSL space in the Stanford Industrial Park (Brandin, 1956a,b, 1957). During SSL's first two years, Shockley would also hire the Stanford Research Institute (SRI) to perform studies for him (Stanford Research Institute, 1955, 1956; Shockley, 1957b,c).[3] For SRI, this represented a return to its original mission of providing assistance to new industries and local firms (Adams, 2005). Also during that first year, Shockley worked out an arrangement with Stanford to use the services of Jim Gibbons, a new engineering faculty member (Lécuyer, 2005). From Stanford's standpoint, Gibbons would bring the latest in semiconductor developments to campus, reproducing the Shockley lab on campus. The benefit to Shockley would be that the next generation of Stanford students would complete their degrees having become familiar with the Shockley lab set-up, making them prime candidates to join SSL. Most of the first generation of Stanford PhDs in the solid-state electronics program would end up with large Eastern firms rather than local start-ups, however; that was the default mode for American engineers during the 1955–1965 period (Lécuyer, 2005). Gordon Moore recalls that subsequently Stanford fueled the semiconductor industry with "its yearly provision of outstanding M.S. and Ph.D. graduates" (Moore and Davis, 2004, p. 17).

[3] Even before Shockley set up shop, Beckman Instruments was an "associate" of SRI (SRI, 1955, p. 44).

The main reason SSL did not reap this benefit is that the enterprise's life as a significant entity was so brief. Shockley was a spectacularly poor manager. His fame had helped Shockley assemble a scientific dream team, including Noyce and Moore. Shockley's abysmal management ability, however, quickly turned them against him. When a division manager's subordinates give up on their boss, they often seek an ally at a higher level in the hierarchy. That is precisely what Shockley's team did. They met privately with Beckman, who then informed Shockley that he was in danger of losing his best men (Riordan and Hoddeson, 1997, p. 249).

The original agreement between Beckman and Shockley said that Beckman would provide "managerial and administration services as may be required" (Beckman, 1955). When the division floundered, Beckman brought in an administrator from the Spinco Division to help right the ship. In September 1957, a year and a half after the formation of the laboratory, eight top researchers, whom Shockley dubbed "the Traitorous Eight," resigned en masse. Arnold Beckman later voiced regret that he had not replaced Shockley with Robert Noyce (Beckman, 1980, pp. 34, 51). Beckman stuck with Shockley for three more years before selling the division to the Clevite Transistor Corporation. International Telephone and Telegraph bought Shockley Semiconductor in 1966, and did what it had done three decades earlier with FTC: moved it to the East Coast. Although Shockley Semiconductor would last until 1968, by October 1957 it was essentially finished as a viable competitor in the Valley (Riordan and Hoddeson, 1997, pp. 269, 275).

The path of the so-called Traitorous Eight reflects a similar environment, but at the same time helped pave the way for another institutional stage of development in the Valley. When they discovered that Shockley's deficiencies as a manager trumped his technical genius, the refugees pursued what the *Solid State Journal* called a "reverse-Horatio Alger" approach, eschewing the "struggle in someone's garage" (Solid State Journal, 1960, p. 1). They asked a New York investment firm to find an existing company that would hire the entire group. Reflecting the apparently limited possibilities at the time, they sought to be employees, not entrepreneurs. They sought "a company which can supply good management" (Lécuyer, 2007, p. 156). When Arthur Rock and Bud Coyle of the investment bank Hayden Stone met with the group, the bankers had a different idea. Gordon Moore recalls: "We got together for an evening and they say, '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 wouldn't even have to move. So that was the entrepreneurial spirit that drove the formation of Fairchild" (Berlin, 2001, p. 71).

Hence, one of the Valley's great entrepreneurs got his first start-up experience as a last resort rather than as a first option. Moore (1994) would later humbly refer to himself as an "accidental entrepreneur." In 1956 and 1957, although they were bold and enterprising, the creators of the Valley's first semiconductor laboratories acted little like 1980s and 1990s entrepreneurs—the local infrastructure (including venture capital) to do so was not yet in place. One thing they did, however, paralleled behavior of later generations of entrepreneurs: they grew where they were planted, staying in the Valley. There, Fairchild Semiconductor joined Stanford's Honors Cooperative and Industrial Affiliates programs (Stanford University, 1959).

The Traitorous Eight's arrangement with Sherman Fairchild was in many ways similar to Shockley's arrangement with Beckman. Fairchild's New York-based Fairchild Camera and Instrument had weighed a possible entry into the semiconductor business for several months; this would help the struggling defense contractor's move toward technology in the gathering, transmitting, and storage of data (Berlin, 2006; Lécuyer, 2000). Sherman Fairchild provided $1.38 million of loans to the group in exchange for control of the company (Berlin, 2006). He controlled the board, had the power to appoint a general manager, and had final say on strategy and resource allocation.

One thing Shockley Semiconductor lacked was anyone with crucial business knowledge, such as how to build an organization and establish key capabilities. For instance, Jim Gibbons, a freshly minted PhD in electrical engineering, was Shockley's marketing "expert." Fairchild Semiconductor faced the same problem, and in that respect was a microcosm of the Valley. Where do you go for business expertise? The answer, in Fairchild's case, was Hughes Semiconductor, the industry's first mover, which had tried to hire Shockley in 1954. Ed Baldwin, the engineering manager at Hughes, not only brought the necessary business skills to Fairchild (he hired a marketing manager!), but also, as Gordon Moore notes, "educated a class of technological managers" (Moore and Davis, 2004, p. 12). More than ten years after the founding of Fairchild Semiconductor, Moore and Noyce would use what they had learned there in shaping a new firm: Intel.

The Traitorous Eight needed help from the East as well. Fairchild Semiconductor's first contract, with the Federal Systems Division of IBM, required intervention from the man on the East Coast perched at the top of the hierarchy. The new company needed IBM more than IBM, which had alternative sources of transistors, needed Fairchild's business. In December 1957, IBM had signed a joint licensing and development agreement with the leading transistor maker Texas Instruments (Chandler, 2001, p. 124). Sherman Fairchild, who was IBM's single largest shareholder, met with IBM's CEO, Thomas Watson Jr., to assure him that buying transistors from Fairchild's new enterprise "was a safe thing to do" (Lécuyer, 2000, p. 168).

Another difference from a 1980–1990s start-up that Fairchild Semiconductor shared with Shockley Semiconductor was that there was a limit on how much money the "founders" could make from the enterprise. Sherman Fairchild had the power to exercise an option to buy the firm for $3 million, an option he exercised in 1959. The Traitorous Eight each received $300,000, but were more employees than owners after that. With their wealth came little control over the operation. The semiconductor division never placed a representative on the company's board, and resources seemed always to flow from the profitable West Coast operation to the East (Berlin, 2006).

The Valley's first two generations of semiconductor enterprise featured major exogenous forces shaping strategy. The most significant difference between Shockley and Fairchild versus subsequent generations of autonomous semiconductor start-ups in the Valley was source of control: the ability to choose leadership and strategy would later come from within the Valley rather than from Fullerton or Long Island. It was the semiconductor industry's third generation of firms that finally supplied the Valley with a host of firms — including those that are now recognized around the world — and expanded the industry's workforce. The process of spin-off had begun almost immediately after Shockley's arrival and then really gained momentum in the late 1960s. As of 1965, the semiconductor industry represented less than one-half of the Valley's employment in electronic components (Lécuyer, 2007, p. 6). The real takeoff, in both enterprise creation and employment in the semiconductor industry, was yet to come. In the 1980s, Intel would become the industry leader and retain that position for many years. Before that, Intel would be most noted for its 1970 development of the microprocessor, which would make the personal computer possible. The development of the personal computer would launch its own host of start-ups, but Silicon Valley's saga in computers also featured large roles for multilocational firms.

6. Computers (storage)

One of Silicon Valley's most frequently repeated stories about the computer industry involves Connecticut-based Xerox, and how its Palo Alto Research Center (PARC) developed the first (albeit non-commercial) personal computer, and then "transferred" key technologies such as the graphical user interface and the Ethernet (local area network) to local companies (Kenney and von Burg, 2000, p. 236). The presence of Xerox in the Valley contributed more to the region's development than to the growth and profitability of Xerox itself (Chesbrough, 2002; Hiltzig, 1999). Xerox arrived in the Valley, however, in 1970—four years after release of Hewlett-Packard's first computer, which came a year after the end of the period under examination in this article (Malone, 2007, p. 176). The Xerox experience is relevant to the 1940–1965 period, however, because in that earlier period, a company based elsewhere played a big role in the region's computer industry activities.

One of the distinctive advantages Silicon Valley holds over other high-tech regions is its close proximity to two world-class engineering programs (Stanford and UC Berkeley). By the 1980s and 1990s, it was commonplace for graduates (and, in some cases, faculty members) to start companies nearby. During the two decades following World War II, however, it was more common for Stanford and UC Berkeley graduates to work for local branches of multilocational firms. During Silicon Valley's period of scaling up, before the advent of the personal computer, local computer industry activity, as in the rest of the country, was dominated by IBM. The major technological contributions from IBM's San Jose research center involved storage technology. Subsequently, members of IBM's San Jose laboratories would launch start-ups, particularly in the area of memory storage.

During the 1940s, federal government funding and university research led developments in computing. "Supercomputers," such as the ENIAC, whose use of vacuum tubes caused them to take up an entire room, were not the only Holy Grail. The Office of Naval Research also funded efforts at UC Berkeley to develop a lower-cost "intermediate" computer. UC Berkeley's CALDIC program began in the late 1940s under engineering professor Paul Morton but the university did not commercialize the technology (Cortien, 2008, pp. 11, 12; Hoagland, 2003, p. 1871). The program's primary benefit to the university would be its attraction of top-flight graduate students. The commercial benefits would accrue first to industry leader IBM, and then to the San Jose region as it became the center of the disk drive industry.

Silicon Valley's leading role in hard disk drives, which would become a $30 billion industry by the 1990s, was made possible because of decisions made in New York (McKendrick et al., 2000, p. 27). After World War II, IBM made a general commitment to becoming a more research-intensive firm. With the backing of executive vice president Thomas Watson Jr. and his CEO father, Thomas Watson Sr., director of engineering W. Walter McDowell presided over a fourfold increase in R&D staff from 1950 to 1955 (Pugh, 1996, pp. 164–165). McDowell wanted more focus on "long-range component development" and saw the virtue of physically distancing research from members of the sales department. Individuals in sales tended to demand that research focus on incremental innovation for the existing product line rather than on more disruptive development. Therefore, in 1952 McDowell dispatched eighteen-year company veteran Reynold Johnson and four others to establish a research laboratory in San Jose (Pugh, 1996, p. 223). San Jose was chosen as the laboratory's location for two reasons (Cortada, 2010):

1. San Jose's proximity to UC Berkeley and Stanford University, and
2. The goodwill IBM had generated locally since construction of a punch card plant in San Jose in 1943.

The first project for the new laboratory was a disk storage device for the IBM 305 RAMAC (Random Access Memory Accounting Machine), using magnetic disk technology, as had UC Berkeley's CALDIC group. Two of Johnson's four primary team members for the project, John Haanstra and Louis Stevens, had studied under Paul Morton at UC Berkeley (Pugh, 1996, p. 227; Hoagland, 1998). The group completed the project in 1956. This did not, however, immediately launch an industry because at the time, IBM had about 70% market share, so the company's internal needs trumped any strategy to sell the storage devices on the open market.

The completion of the San Jose lab's next big storage project was handled by Alan Shugart, who would become the foremost individual in transferring disk drive technology from IBM into the local area, thereby establishing an industry. The lab subsequently became an incubator for start-ups; Valley-based companies such as Memorex, Quantum, and Maxtor owe their origins either directly or indirectly to IBM's local presence (Bahrami and Evans, 2000; Kenney and von Burg, 2000).

The disk drive industry grew where IBM had planted it. IBM's San Jose laboratory became a major source of innovation in magnetic data storage, employing more than four thousand people by the 1970s (Kean, 1977, p. 12). By 1970, one-third of all hard disk firms were headquartered in the Valley (McKendrick et al., 2000, p. 90). After heading research for Memorex, in 1973 Shugart led a team including several IBM expatriates that began Shugart Associates, the first notable manufacturer of floppy disks—which IBM had invented in 1971 (Christensen et al., 1996, p. 3). Six years later, Shugart cofounded Seagate Technology, which created the first 5.25-inch hard drive for the personal computer. Seagate became the storage industry leader, with more than fifty thousand employees and $10 billion in sales annually. Shugart was following a well-trod entrepreneurial path by starting firms in the region where he lived (McKendrick et al., 2000, p. 41). As McKendrick puts it: "The [disk drive] industry was born in San Jose, California, and the region hosted more disk drive startups than any other place on earth" (p. 11).

Along the way, IBM established an intimate relationship with Stanford University. By 1960, IBM's San Jose laboratory had joined Stanford's Industrial Affiliates Program in solid-state electronics as well as Stanford's Honors Cooperative Program. One of the results was that IBM's San Jose laboratory became a principal node in one of the Valley's foremost networks of innovation (Fleming and Marx, 2006; Fleming and Frenken, 2006). During the 1990 s, IBM would spin off more start-ups than Stanford University did (Zhang, 2003: 50). The benefits were not, however, unidirectional. Presence in Silicon Valley's largest collaborative cluster would help IBM's move into the life sciences (Fleming and Marx, 2006, p. 14). In computers, as in semiconductors, the seed was planted by exogenous firms, and start-ups would come later—mainly after 1965.

IBM did more than seed the disk drive industry and establish an active network of innovation. The company's impact extended — at least indirectly — far beyond computers and peripherals. In 1954, IBM was one of four large companies that petitioned the University of California to set up a graduate engineering program in the Valley. UC Berkeley, which had the institutional standing to meet their needs, seemed reluctant to do so. San Jose State, which was eager to meet their needs, lacked the institutional standing to do so. After three years of inaction, assemblyman Bruce Allen (representing Santa Clara Valley) complained to Governor Goodwin Knight in a letter that mentioned local employers Lockheed, General Electric, and Westinghouse. The ultimate result was the 1959 accreditation of San Jose State's engineering program and permission for SJS, beginning in 1959, to grant advance degrees in engineering. San Jose State subsequently became the leading source of engineers in Silicon Valley (Adams, 2010). So even indirectly, during the period prior to 1965 the local branches of multilocational firms played a big role in shaping the high-tech future of Silicon Valley.

7. Aerospace

Just as the computer industry came to the Valley in part because IBM wished to be near Stanford and UC Berkeley, aerospace came to the Valley in part because Lockheed wished to be near Stanford and the Valley's local electronics capabilities. Beyond that, however, contrasts outweighed the similarities. Whereas the computer industry came to the Valley partly because IBM's researchers needed to operate more independently of customers' desires, the aerospace industry came to the Valley as part of a larger strategic effort by Lockheed to develop a new line of business and cultivate a major customer. Whereas IBM was an industry leader trying to secure its long-term viability through an increased commitment to research, Lockheed represented a late mover among airframe companies into missiles and space. Whereas the IBM laboratories would generate many spin-offs, Lockheed's missiles and space division would not.

From its founding in 1913 until the early 1950s, Lockheed had identified itself as an airframe producer. After World War II, however, the company's primary customer, the U.S. military, made it clear that missiles and space represented the new frontier for defense contracting. Lockheed had more relevant organizational capabilities and experience than most, but simply chose not to enter the market until pressure from the military became too great to ignore. Therefore, Lockheed did not appear on lists of major contractors for missile development projects from the mid-1940s until the mid-1950s (Schoenberger, 1997, pp. 161–162).

Entering missiles and space meant greater emphasis on scientists—especially physicists (as at Hughes Aircraft during the 1946–1953 Simon Ramo era), and until the early 1950s Lockheed's technical expertise came from engineers. Lockheed established its missiles and space division (LMSD) in January 1954, before the company had any major contracts; the main purpose of this apparent cart-before-horse move was to signal to its primary customer the seriousness of the company's commitment to a new identity. Division general manager Pete Quesada trotted out Hughes Aircraft as a prime example of a company that "made a nearly complete change from whatever it was to what it is" (Schoenberger, 1997, p. 166).

Stanford's role in aeronautics paralleled that of Lockheed. Just as Lockheed was an early (and major) airframe maker, Stanford was an early (and major) player in aeronautical engineering. Professor William Durand, an expert on propeller design, helped found (in 1915) and served as the second chairman of the National Advisory Committee for Aeronautics (NACA), the predecessor to NASA (Leslie, 1993, p. 103). By 1934, Stanford was one of only three universities (along with MIT and Caltech) accredited by the American Council on Education to grant doctorates in aeronautical engineering (Leslie, 1993, pp. 106–107).

Following World War II, however, both institutions went into decline. At the same time Lockheed was a non-player in missiles and space (prior to 1954), Stanford's aeronautical engineering program was on life support: Dean Terman considered pulling the plug. Upon learning of the program's predicament, industry officials sprang into action. Led by Stanford aeronautical engineering alums John Buckwalter (project engineer for Douglas Aircraft's DC 4) and Philip Coleman (chief aerodynamics engineer at Lockheed), they raised a war chest to save the program.

In November 1955, Lockheed announced purchase of a 275-acre site in Sunnyvale and a twenty-five-acre site less than ten miles away in the Stanford Industrial Park (Boyne, 1998, p. 274). The latter would house the division's research laboratories, and the former would house the rest of the division. Lockheed needed room for future growth, something its Southern California locations (Burbank and Van Nuys) lacked but Santa Clara County could offer. The proximity of LMSD to Stanford was no accident. Once the company decided to move the division away from Southern California, options included locations near MIT, Princeton, and Stanford (three schools with track records in aeronautical engineering). Lockheed's president, Robert Gross, emphasized the attraction of Stanford. In a press release announcing the division's move, Gross noted that the Bay Area had become a center of electronics activity, and emphasized the value of proximity to the cutting-edge research at Stanford University and at Stanford Industrial Park. Dr. Lewis Ridenour, Lockheed's research director, said that the company sought both educational and research benefits in its relationship with Stanford (Lockheed, 1956).

The military had also encouraged the dispersal of the aerospace industry from its principal hub around Los Angeles for strategic and security reasons. Setting up the operation to be separate and geographically distant from Lockheed's Burbank corporate headquarters represented an effort to establish a culture separate from that of the airframe side of the business, and to demonstrate that effort to the military (again through making an extraordinary commitment in advance of any major contract) (Schoenberger, 1997, p. 171). Distance from headquarters was a push incentive for the division, and proximity to Stanford proved a crucial pull (Leslie, 1993; Schoenberger, 1997). The strategy worked: in December 1955, the Navy chose Lockheed as prime contractor to manage a new submarine-based ballistic missile system (Boyne, 1998, pp. 278–280).

The final variable Lockheed considered was proximity to the aerodynamics capabilities of NACA's Ames Research Center, which had opened in 1940. The Ames Center triangulated with the military and industry: the military asked NACA what was possible, and then asked industry to do it. Industry, in turn, sought NACA's advice on how to do it. Ames ended up in Sunnyvale as part of an effort to diversify NACA's locations beyond Langley, Virginia, in order to decrease vulnerability to a single foreign attack (Roland, 1985, pp. 154–155). Ames was, as Stuart Leslie notes, "staffed top to bottom with Stanford graduates" (Leslie, 1993, p. 118). The rise of Ames had coincided, however, with the decline of Stanford's aeronautical engineering program. By the mid-1950s, when Ames researchers sought advanced degrees, they often chose the option of Caltech (more than 400 miles away) rather than Stanford (a few miles away).

The Stanford/Ames relationship would intensify when Stanford's program improved, and there the industry war chest and the Lockheed/Stanford connection made a big difference—especially regarding Nicholas Hoff. Hoff, a 1942 Stanford graduate, established an aeronautical engineering program at Brooklyn Polytechnic College. There he consulted for various companies, including Lockheed. In July 1956, Willis Hawkins, director of engineering for LMSD, offered Hoff a full-time job to explore the impact of heat on missile re-entry. Hoff, who wished to maintain a university connection, turned Hawkins down (Leslie, 1993, pp. 116–117). Hawkins, Hoff, and Terman then worked out a deal by which Hoff became a Stanford professor and a Lockheed consultant, with Lockheed paying half his salary (Hawkins, 1956; Terman, 1956b). Meanwhile, the head of Ames's supersonic wind tunnel, Walter Vincenti, who had turned down a previous offer from Stanford, accepted a position with his old friend Hoff.

Within three years of the Hoff deal, Stanford's aeronautical engineering program had grown to ten faculty members, ninety-two graduate students, and $460,000 of contracts—a vast increase over the 1956 levels of two faculty members, twelve graduate students, and $45,000 in contracts (Leslie, 1993, p. 119). By 1961, missile systems represented more than half of Lockheed's business and Lockheed had become the first firm in the Valley to employ more than ten thousand workers (Schoenberger, 1997, p. 174; Heinrich, 2002, p. 258). Along the way, Lockheed became a central player in Stanford's outreach programs to industry. Lockheed dominated the Honors Cooperative program, enrolling more students than any other firm. Lockheed was a key player in the affiliates program for aerospace, and its LMSD research facility was one of the largest tenants at the Stanford Industrial Park (Adams, 2005).

Lockheed's strategic move to the Valley would shape the local aerospace industry. In 1957, Philco's aerospace research entity, Western Development Laboratories (WDL), moved to the Valley to be close to Lockheed, its prime contractor (Schoenberger, 1997, p. 178). Like Lockheed, Philco was attracted by access to Stanford's engineering expertise (and graduates), and like Lockheed, Philco became a tenant at Stanford Industrial Park for research laboratories. Like Lockheed, Philco worked with the Ames Research Center (Leslie, 1993). Philco sold the WDL to Ford in 1961. As the lab changed hands and grew to seven thousand employees, one thing did not change: control remained thousands of miles away (Heinrich, 2002).

Westinghouse arrived in the Valley before Lockheed did, but became a player in missiles and space in a different manner. Instead of moving an aerospace division to the Valley, Westinghouse moved its Sunnyvale Marine Division in a new direction. The Marine Division was the result of Westinghouse's 1947 purchase of the Hendy Iron Works, which had produced engines and turbines for Navy and Maritime Commission ships during World War II. Westinghouse was also concerned about a competitor: it wanted to establish a beachhead in the Bay Area to match General Electric's presence in Emeryville in anticipation of California's postwar growth and associated increased need for equipment by Pacific Gas and Electric, the state's primary utility. In the mid-1950s, the focus of the Marine Division changed: Westinghouse became a subcontractor (to Lockheed) for missile launchers, and by 1960 it employed more than 2500 in Sunnyvale. The Marine Division remained in the missiles and space business for the duration of the Cold War (Cabral, 1991; Heinrich, 2002).

Of the Valley's major high-tech industries in the period ending in 1965, aerospace would generate the smallest number of spin-offs. Part of this had to do with barriers to entry based on capital requirements and scale. As Arnold Cooper noted in his study of 1960s Silicon Valley entrepreneurship: "Large firms are often engaged in activities which require heavy capital investment or large organizations to compete: economies of scale are often important" (Cooper, 1971, p. 27). Does that mean that the critical mass of engineers the aerospace industry attracted made no contribution to the entrepreneurial Valley of the 1980s and 1990s? No. It means that some of the industry's lasting impacts on the Valley were more indirect. For instance, Gordon Moore, one of the "Traitorous Eight" who jumped ship from Shockley Semiconductor in 1957 and went on to cofound Fairchild Semiconductor and Intel, took advantage of an interview trip to Lockheed in order to interview for a job with Shockley as well (Riordan and Hoddeson, 1997).

The industry's impact may also have lagged a generation. During a 1947 radio program, a Stanford student asked Frederick Terman if engineering was "open to women who can meet the qualifications which you speak of." Terman answered that he could not "give much encouragement. Marry an engineer and understand" (Terman, 1947). That answer makes one cringe today, but it carries an important kernel of truth: One of the challenges confronting less represented groups in high-tech is the hidden value of having a family member in that world. The techies who launched the personal computer industry in the 1970s, and software and Internet firms in subsequent years, benefitted from growing up in a region in which many engineers (including family members) lived. Jeff Goodell's family memoir *Sunnyvale* provides an excellent example of this generational phenomenon. Goodell's grandfather was an "ur-geek" for Westinghouse who arrived in the Valley in the 1950s. Goodell's mother worked for Apple beginning in the late 1970s, and his sister — who learned to love computers hanging out near her mom's cubicle — joined Excite@Home in the late 1990s (Goodell, 2000, pp. 92, 245).

Blue Sky Dream, the memoir of David Beers, focuses on his father, an engineer at Lockheed. One of the engineers Mr. Beers worked with had a son who also turned into a techie: Steve Wozniak (Beers, 1997). Freiberger and Swaine refer to Steve Wozniak as a "prototype." The reason? "Many students at Homestead High had parents in the electronics industry, and these kids were not intimidated by new technology. They had grown up with it. They were used to watching their fathers work with oscilloscopes and soldering irons" (Freiberger and Swaine, 1984, p. 204). Established companies such as Lockheed seeded the Valley not just with specific know-how but with a general interest in and comfort with science and technology that would help make future start-ups possible.

8. Conclusion

During the years 1940 to 1965, the area that would become known as Silicon Valley emerged as a formidable high-tech region. This article has demonstrated that this came about in no small part because of the actions of multilocational firms based elsewhere. Not until after this period was there an infrastructure of venture capital firms and law firms based in the Valley, and not until the 1980s and 1990s did the Valley's academic anchor go beyond its role as technological magnet for distant firms to become a prolific incubator of high-tech start-ups. One study from the late 1990s suggests that nearly two thousand of the Bay Area's high-tech firms were founded by Stanford alumni or faculty (Byers et al., 2000). Another study indicates that even after excluding the impact of Hewlett-Packard (the Valley's largest indigenous firm), in both the 1980s and 1990s more than half of the revenues of companies based in the Valley came from firms either started by Stanford students or professors or using technology developed at Stanford (Gibbons, 2000).

In 1988, William Hewlett suggested that he had seen far more change in the Valley in the previous twenty years than in the first thirty after the founding of H-P (Gibbons, 2000). Not only had the Valley's high-tech industry grown tremendously, but the dominant mode of enterprise had shifted the local start-up. One-third of the largest high-tech companies established in the United States from 1965 to 1990 were based in the Valley (Saxenian, 1996). A formidable infrastructure to support new enterprise had arrived and was the envy of the world. Control had shifted from outside of the region to inside it.

The findings of this study may have important ramifications for other regions: for example, the significance to regional development of location decisions by large, established high-tech companies, and the relationship of such decisions to clustering and agglomeration benefits such as knowledge spillovers, access to capital, and proximity to customers, suppliers, and labor. Such choices made by outsiders not only provided a critical mass of high-tech jobs in the Valley but also allowed entrepreneurs to gain experience working as employees in industry locally, and to work with experienced managers, before launching their own start-ups.

The idea that Silicon Valley grew up principally around indigenous start-ups begs the question of where the Valley's firms garnered their organizational capabilities. The success and fame of the "H-P Way" has planted the idea that the Valley simply invented a new style of management from scratch as it went along. Lécuyer (2003) advances another possibility: that management practices in the Valley were influenced from the outside by General Radio, a Massachusetts firm. My research suggests an additional influence: that the Valley imported its managers (and, at least initially, its managerial style) through satellite operations of IBM, GE, Lockheed, Westinghouse, and similar large, established companies based outside the region. Prior to 1965, decisions in New York, Schenectady, Burbank, and Pittsburgh played a large role in shaping the region, just as decisions made in Palo Alto, Santa Clara, and Sunnyvale.

As we have seen in Silicon Valley, exogenous factors play a major role in developing high-tech regions as multilocational firms seek proximity to sources of technology, a ready supply of knowledge workers, and the promise of access to customers. The host regions benefit from the injection of capital and organizational experience—crucial elements in spawning an entrepreneurial region. Host regions run the risk that "footloose" multinational firms will pull up stakes and move away, as happened in the Valley's early years. During the development of a region, the local research university can sustain the region's knowledge base and act as a magnet for high-tech industry. Once the region attains a critical mass of high-tech talent, then indigenous enterprise — which is less likely to move — assumes greater importance. Attracting foreign direct investment or a domestic equivalent does not represent an abdication of local power and control, so long as an academic anchor acts like a magnet holding the industrial cluster together until critical mass is achieved.

Those who observe today's entrepreneurial Valley may identify its roots in Hewlett and Packard's humble garage on Addison Street in Palo Alto and conclude that with enough garages you can build a high-tech region. The appeal of the garage-based entrepreneurial myth is powerful—and represents part of a more complex reality (Audia and Rider, 2005). Silicon Valley boasts countless stories — from Hewlett-Packard to Apple to Google — of spectacularly successful garage-based start-ups, and those stories fuel the dreams of millions of aspiring entrepreneurs. By contrast, how many dream of being the individual who proposes locating an operation of his or her multilocational firm near a research university thousands of miles from headquarters? Yet the various exogenous factors at work in the Valley from 1940 to 1965 suggest that building a high-tech region may require much more than local creativity and entrepreneurship. It may require, in addition, the accretion of a critical mass of high-tech activity, organizational capabilities, and investment that depends on the attraction to the region of branches of established high-tech companies. The establishment of a high-tech region may rely as much on the actions and decisions of managers in established large-scale companies as on those of entrepreneurs.

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[4] The following abbreviations will be used in this section: CU: University of California Archives. SC: Stanford University Archives, Special Collections.

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