3 The Research Laboratory: Silicon Valley's Knowledge Ecosystem

Silicon Valley is an ideal research laboratory for studying super-flexibility. Living on the cutting edge of technology and innovation, nothing stays stable for long. Competitive landscapes habitually transform, almost overnight. New start-ups keep the incumbents on their toes. Multi-cultural entrepreneurs bring in diverse recipes from all over the world. Knowledge workers change jobs and move between assignments. New players create novel solutions; and today's successful "stars" habitually become tomorrow's "black holes".

Although Silicon Valley has endured explosive growth, punctuated by several economic downturns, during the past 30 years, it continues to be a global center for high tech innovation and entrepreneurship. It is the epicenter for global venture capital and attracts entrepreneurial talent from all over the world. Although time will tell whether this trend will continue in the future, Silicon Valley has shown considerable resilience in the face of skepticism about its continued viability. This chapter examines the special features of Silicon Valley, its historic antecedents, its core building blocks, and its relevance as a research laboratory for studying super-flexibility.

There are a number of precedents for studying flexibility in circumscribed settings, bounded by time frames, industries, or societal conditions. As discussed in Chapter 2, the Great Depression of the 1930s unleashed a number of pioneering studies on the notion of flexibility (Hart 1937a, 1937b, McKinsey 1932, Stigler 1939). The focus of these studies was on creating new businesses, and farmers' response to oscillations in the price of agricultural produce (Backman 1940, Mason 1938, Nicholls 1940). Later "strategic-flexibility" was studied from the vantage point of corporate responses in the immediate aftermath of the 1973 Oil Crisis (Eppink 1978a, 1978b). The notion of "resilience" was examined by studying natural ecosystems and the impact of human expansion (Holling 1973). Recently, "strategic resilience" has been proposed as a means of re-inventing large corporations (Hamel and Valikangas 2003).

Silicon Valley has been at the forefront of many contemporary trends in business. For example, the practice of "offshoring" was initiated by the region's disk drive and semiconductor industries during the 1980's. Firms in the Valley are early adopters of new technologies and serve as beta-test sites for local companies. We believe Silicon Valley can provide practical insights on super-flexibility in an age of technological discontinuity, economic uncertainty, and global entrepreneurship.

"*Our firms need to be flexible to stay competitive; however, flexibility for firms translates into anxiety for our workers. The new employment environment is characterized by turbulence, uncertainty and the need for adaptability in the following ways: more frequent employer switches, shorter job tenure, required retraining/skills up-grading, frequent wage gaps and fluctuation, increasing self-employment, and required geographic mobility*" (Index, Joint Venture Silicon Valley, 2008).

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We characterize Silicon Valley as a "Darwinian", dynamic, knowledge ecosystem. The term "ecosystem" is defined here as a "community of autonomous players, that function interdependently, that feed off, compete and collaborate with one another, and that operate within a common climate". Its core building blocks include:

- **The "knowledge originators":** including universities and corporate and government research laboratories, nurturing talent, ideas, and emerging technologies.
- **The "knowledge hatcheries":** the critical mass of seasoned entrepreneurs, "angel" investors, and venture capital firms, providing risk funding to seed start-ups and fuel their growth.
- **The "knowledge generators":** the cluster of emerging start-ups, mid-sized adolescents, and established giants that produce innovative products and services. They also provide the entrepreneurial talent pools from which many spin-offs are drawn.
- **The "knowledge lubricants":** the groupings of specialized lawyers, accountants, executive search specialists, consultants, and other service providers that provide a complementary support infrastructure.

Enterprises in Silicon Valley are embedded in symbiotic and interdependent relationships with the broader ecosystem. Buyers become suppliers; customers turn into competitors; partners become vendors. The close physical proximity between firms, and the incessant movement of people, ideas and information create a setting that is analogous to a biological ecosystem. The walls between the "enterprise" and the ecosystem are not solid but opaque and decidedly permeable.

3.1 Conceptual Underpinnings

The ecosystem concept is not new or limited to Silicon Valley. Indeed, clusters of firms in related industries have historically coalesced around a critical mass of business activity (Porter 1990). During the 19th century, for example, many firms in Birmingham, UK, clustered around the critical mass of expertise in, what is known in the vernacular as, "metal bashing".

The automobile sector amassed around Birmingham (U.K.), Detroit (U.S.A.), and Stuttgart (Germany) during the 1900s. In the City of London, financial industries have evolved around the famous "Square Mile". Similarly, Italy's textile industry has coalesced around the city of Prato. High technology industries of the information era also conform to this clustering tendency.

Several regional technology clusters have sprouted around the U.S. during the past two decades, including Boston's "Route 128", Austin's "Silicon Hills", Seattle's "Technology Corridor", Illinois' "Silicon Prairie", New Jersey's "Princeton Corridor", San Diego's "Golden Triangle", and Utah's "Software Valley". Scotland's "Silicon Glen" and Cambridge's "Silicon Fen" have also attracted many

technology-based companies. During the 1980s and early 90s, Singapore, and later Bangkok, became centers for disk drive and computer sub-systems manufacturing. India's Bangalore region, today the hotbed of entrepreneurial companies, built its reputation in Unix programming. Additionally, a number of government sponsored science park initiatives, such as France's Sofia Antipolis, and Taiwan's Hsinchu, have also induced a critical mass of technology companies. By far, the best-known cluster of high technology firms is located in California's Silicon Valley.

According to the "2008 Index of Joint Venture Silicon Valley", the region covers an area of 1,854 square miles in the San Francisco Bay area, has a population of 2.52 million, and is home to 393 public companies and more than 22,000 high tech establishments. Its economy has evolved during the past 30 years, triggered by periodic emergence of disruptive innovations. Initially boosted by defense spending during the 1960s, the epicenter of innovation shifted to semiconductors and integrated circuits in the 1970s, evolved to personal computers, disk drives and peripherals during the 1980s, was dominated by software, search engines, Internet services, and disk archiving in the late 1990s, and has gravitated towards clean tech, social networking, and life sciences during the last five years.

3.2 The Evolution of Silicon Valley

There was no singular event or grand plan which led to the meteoric rise of "Silicon Valley".[1] Instead, a series of independent events, coupled with fortuitous timing, transformed a regional agricultural community into a global engine for technological innovation and entrepreneurship. The region evolved organically over time, when several complementary forces gelled together and resulted in the formation of a critical mass of high technology firms.

From a technological perspective, the parallel development of two major innovations forged the foundational building blocks that underpinned the rapid growth of Silicon Valley during the 1960's and 1970's. The first, and the best-known of these, was the commercial development of the transistor at AT&T's Bell Labs in 1948. The second was the development of disk drives or information storage technology using magnetic recording techniques. Using tape in 1953 and magnetic disks by 1957, the technology was developed at IBM's Santa Theresa Research Laboratory (Harker et al. 1981).

William Shockley invented the transistor at Bell Laboratories in New Jersey in 1947. He moved to Palo Alto, his home town, in 1954 and set up Shockley Semiconductor Laboratories. His core tem of eight scientists became the founding nucleus for the growing West Coast semiconductor industry.

[1] Addressing a meeting of the Churchill Club (October 1992), Bill Hewlett suggested that the origins of Silicon Valley, in his opinion, almost date back to the development of ship-to-shore radio and the early days of television, before RCA moved its R&D labs to the East coast.

They left Shockley Lab in 1957 and founded Fairchild Semiconductor. Further advances in semiconductor technology and the emergence of a major market in the defense industry helped launch many spin-offs, largely out of Fairchild, during the 1960's; among them National Semiconductor, AMI, Advanced Micro Devices and Intel.

During the same period, IBM set up its "skunk works" in Los Gatos with the aim of producing technical breakthroughs and innovative products. The development of Winchester disk drive technology[2] later led to the formation of a multi-billion dollar industry in Silicon Valley (Mulvany et al. 1975, Stevens 1981). Several members of the IBM team were later responsible for the founding of Memorex, Shugart, Seagate, Conner Peripherals, Adaptec, Auspex, Maxtor, and Quantum. The disk drive industry has been a major source of innovation and international dominance for US companies.[3] Chapter 4 reflects on the early evolution of this defining sector in Silicon Valley.

Stanford University's Dean of Engineering, Frederick Terman, played a crucial role during the early years by forging a close working relationship between the Engineering School and the emerging local firms. The formation of the Stanford Industrial Park in 1951 was an additional catalyst. It became a mechanism for transferring technology from the university to the nearby firms.[4] During the 1960's, the Park became an attractive location for the growing electronics companies. Their number expanded steadily, from 32 in 1960, to almost 70 by 1970 (Rogers & Larsen 1984).

Boosted by California's unique pioneering spirit, these building blocks became the foundation of Silicon Valley. Since the days of the Gold Rush in the 1850s, and later the "Dust Bowl" migration during the 1930s, California, the frontier land, had attracted the risk-takers, the innovative and the ambitious (Kotkin & Grabowicz 1982). It is hardly surprising that many entrepreneurs, who felt the need to challenge the status quo and to break with tradition, found a conducive home in Northern California. By the mid 1960's, a critical mass of technology companies had been established in the San Francisco Bay Area. Santa Clara Valley was transformed from prune yards and orchards into a large Petri dish for creating entrepreneurial ventures and knowledge-based enterprises.

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[2] The team included L.D. Stevens and Ken Houghton, who later became the Dean of Engineering at Santa Clara University.

[3] The US disk drive industry is dominant in merchant production, although much of its manufacturing is offshore, or in partnership with Japanese companies. The industry remains vibrant, as attested by the sustained growth rates and the pace of new product development (McKendrick et al. 2000).

[4] The first tenant was Varian Associates, a spin-off from Stanford University's Physics department. Hewlett Packard followed in 1954. David Packard and Bill Hewlett, Terman's former students, had co-founded Hewlett Packard in 1939.

During the past 30 years, Silicon Valley has nurtured the growth of many global technology companies. Well-known examples include Intel, Apple, Seagate, Adobe, Cisco, Oracle, Symantec, E-bay, Intuit, National Semiconductors, Electronic Arts, Yahoo, Google, and Sun Microsystems. In addition, Silicon Valley is home to several thousand start-ups and mid-sized technology enterprises. As indicated in Table 3, dominant industry clusters include information products & services, life sciences, innovation services, and business/ community infrastructure.

Sector	Number of Employees	Percentage of total Silicon Valley employment
Information products & services	285,614	20.5
Life sciences	33,311	2.4
Innovation & specialized services	152,218	10.9
Business infrastructure	64,187	4.6
Community infrastructure	790,534	56.8
Other manufacturing	66,381	4.8

Table 4. Silicon Valley's major areas of economic activity 2007
(Source 2009 Index, Joint Venture Silicon Valley)

3.3 The Building Blocks

Several specialized building blocks, each playing different yet complementary roles, have turned Silicon Valley into an interdependent knowledge ecosystem. There are several major groupings. These range from universities and research labs, to angel investors and venture capital, support services, and core enterprises. Based on their unique contribution, we characterize these as "originators", "hatcheries", "generators", and "lubricants". This classification is somewhat rudimentary and is not meant to be a comprehensive taxonomy of the various "species" in the ecosystem. Without extending the parallels with the biological analogy too far, the remainder of this chapter describes the core building blocks and the "climate" of this ecosystem. We conclude by reflecting on why Silicon Valley has been an effective learning laboratory for studying dynamic adaptation.

3.3.1 The Knowledge Originators

A knowledge ecosystem incubates new ideas and nurtures their practical development into innovative products and services. In Silicon Valley, innovations are largely based on technological breakthroughs. In this context, universities and research institutes are the ecosystem's most visible building block. They are a critical source of early stage technologies and train technical professionals who become entrepreneurs and knowledge workers. In a nutshell, they are the ecosystem's "originators".

Silicon Valley is a magnet for multi-cultural knowledge workers from different parts of the world. Many come to attend the region's universities and remain in the area; others are recruited to work for Valley-based companies overseas and may transfer back to the home base. Since high technology firms are global from their inception, multi-cultural knowledge workers facilitate rapid development of global operations. Based on 2008 data from the non-profit organization, Joint Venture Silicon Valley, 36% of Silicon Valley's population was born outside the US.

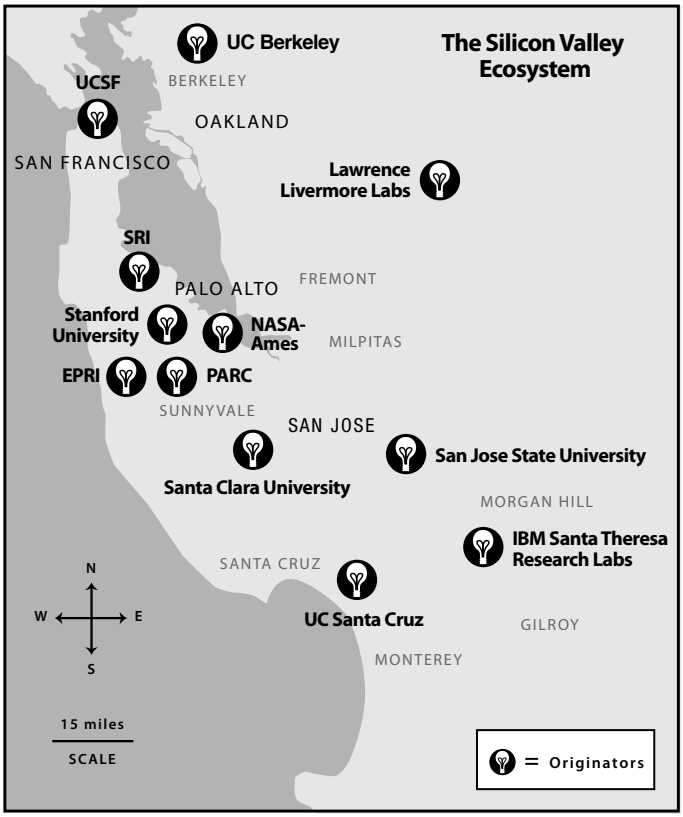

Figure 7. Silicon Valley's knowledge originators

Universities also catalyze networking and relationship building among future entrepreneurs. Social links and collegial relationships play a crucial role during the process of venture creation and enterprise formation. For example, two IT professionals from the Stanford Business School and the Computer Science Department co-founded Cisco Systems in the mid-1980s. Sun Microsystem's co-founders included two Stanford MBA students, a graduate student from the Stanford Engineering School, and a PhD student from Berkeley's Computer Science Department. All four founders of ROLM were graduate students at the Stanford Engineering School, as were Yahoo's co-founders, Jerry Yang and David Filo. "Google" was founded by student friends Sergey Brin and Larry Page, who according to the official history of the firm "were not terribly fond of each other when they first met at Stanford University as graduate students in Computer Science in 1995". [5]

From time to time, faculty members also start companies. For example, Bill New, a professor at the Stanford Medical School, co-founded Nellcor in 1981, a medical electronics company that developed the oximeter as an indispensable aid for anesthesiologists. John Hennesy, who later became the President of Stanford University, was a co-founder of MIPS during the early 1980s. Silicon Graphics was founded by Jim Clark of Stanford's Computer Science Department. He later co-founded Netscape with a young research student, Marc Andresson, from the University of Illinois. Apart from SGI and Netscape, Clark was also a co-founder of MyCFO and Healtheon during the Internet boom years. He later funded the Bio-X facility at Stanford. The goal is to cross-fertilize medicine and biology with computer science and engineering. Ed Penhoet, Dean of the School of Public Health at the University of California, Berkeley, was a co-founder of Chiron. Many faculty members are also advisors, consultants, and board members of growing companies.

Corporate research institutes have also played a crucial role in generating technological expertise. Sometimes, as is the case with IBM's storage research center in San Jose, the pioneer of the Winchester disk drive, the parent can benefit from the R&D innovations. Other times, the technical breakthroughs may not pay off for the parent but can benefit the ecosystem as a whole. A case in point is Xerox's Palo Alto Research Center or PARC. Bob Metcalfe, a research scientist at PARC, developed the Ethernet, the foundation of local area network technology (LAN). He left Xerox in 1980 to form 3Com and went on to commercialize the technology. Similarly, Chuck Greschke and John Warnock developed the Postscript technology at Xerox PARC, but later spun-off to form Adobe Systems during the early 1980s.

Local research institutes have also been responsible for several pioneering technologies. Optical disk drives, the mouse pointing device, and the magnetic ink character system for bank checks, for example, were all initially developed at the Stanford Research Institute (SRI International); Funding from public institutions, such as DARPA (Defense Advanced Project Research Agency) and NSF (National Sci-

[5] Source: www.google.com/corporate/history.html.

ence Foundation), or from private foundations, have also been critical in promoting basic research and its targeted application.

A distinguishing feature of local universities is their open attitude towards information exchange, and the opportunities they provide for cross-fertilization between business and academia. Collaboration may take the form of joint research projects, exchange of staff, or hosting of conferences and networking forums. During the early 1990s, for example, UC Berkeley's Haas School of Business started the first entrepreneurial incubator. The initial goal was to provide facilities for graduating students to start their own ventures. Haas' Lester Center for Entrepreneurship provides the students with contacts in the legal, accounting and venture communities. Both Stanford and Berkeley leverage a broad range of adjunct faculty in their medical, business, computer science, and engineering schools. These experienced entrepreneurs and professionals bring in experience, expertise and valuable connections.

The interlinked processes of cross-fertilization, collaboration, networking, and information exchange are critical in the formation of new entrepreneurial ventures. Some involve formal exchanges, job transfers, or temporary internships. Others include collaborative research or R&D funding. This emphasis on nurturing "open borders" between universities and other building blocks of the ecosystem has been a critical success factor in nurturing innovation, commercializing new technologies and creating new ventures.

3.3.2 The Knowledge Hatcheries

In order to commercialize new breakthroughs, entrepreneurs need catalysts who can incubate and "hatch" their ideas by providing risk capital, relevant contacts and early feedback. Angel investors and venture capitalists are the crucial catalysts in this context. They provide the capital, the expertise, the discipline, the network, and ultimately the "runway", to help fuel the growth of new entities.

Risk capital providers are a crucial component of the Silicon Valley ecosystem (Kenney & Florida 2000). Although one can overstate the importance of venture capital, the community is responsible for accelerating the growth of new ventures by providing funding, management know-how and market feedback during the crucial early stages. Armed with networks of relevant contacts, they augment founding teams, especially as a venture evolves through different stages of development.

Silicon Valley accounts for 30% of all US venture funding and has the world's largest venture capital cluster.[6] The vast majority of venture capitalists are, in the main, responsible for funding new ventures after the initial "seed" stage. Typically, co-founders and private investors provide the initial seed funding. This enables

[6] Source: Joint Venture Silicon Valley Index 2008, P. 14.

a start-up to develop a prototype, although several rounds of financing are typically needed to ramp up its growth. Critical activities include forging distribution channels, generating reference accounts, developing product enhancements, and engaging in global expansion. The principal role of the venture capitalists is to provide the funds necessary to "ramp" the enterprise into a sizable business by providing the "runway" so it can take off .[7]

Start-ups need several rounds of financing before they are in a position to generate sufficient revenue and earnings growth to embark on a liquidity event, such as an initial public offering, or an acquisition by another company. The "lead" investor may help with follow-on financing and the IPO or the acquisition process.[8] Moreover, forged relationships between entrepreneurs and venture capitalists may endure over and above any one venture. They may fund the entrepreneurs' next start-up, or invite them to join their venture firm as limited partners, general partners or venture partners. A number of established venture capital firms have "entrepreneurs in residence" programs, an opportunity to leverage the knowledge, the capabilities, and the experience of seasoned entrepreneurs who may be in-between assignments. They may be enlisted to review deals, to jump-start a portfolio company, or to provide ideas for hatching a new start-up.

3.3.3 The Knowledge Generators

Silicon Valley is well known for its track record in generating a critical mass of technology companies. By far, the most significant building block of the ecosystem is the broad variety of fledgling start-ups, mid-sized adolescents, and agile giants that make up the diverse pool of knowledge "generators". They bring together the talent pools, the ideas, and the technical breakthroughs in order to create new products and innovative services for global markets.

Successful ventures experience rapid growth and evolve through various stages of development in quick succession. The embryonic phase spans the time that the business idea is first conceived to the time that the prototype is developed. This stage is characterized by formation of the founding team, development of a plan of action to capitalize on a new idea, a market opportunity or a technological break-

[7] One of the driving forces behind the historically high growth rates is the structure of venture capital limited partnerships that in the past have typically lasted for 7-10 years. In order to show a return to the shareholders, investors need to liquidate their positions within the time frame specified by the limited partnership. Therefore, the exit strategy of a portfolio company has to be orchestrated within this time frame, so the proceeds can be shared among the partners and the investors. Venture capitalist's often hedge their bets by investing in several firms vying for dominance in a given arena. Even the most seasoned venture capitalists may be unable to spot winners early on, as witnessed by their initially unfavorable reactions to ROLM, Seagate, and Adaptec, among many other successful ventures.

[8] Venture capitalists rarely invest alone in a deal, but with a group of other venture capital firms. A historical description of the role of venture capital in Silicon Valley is in Hambrecht (1984).

through, raising capital from "angels", seed investors, family and friends, and developing the first prototype. Typically, there is a high level of optimism, focus on funding and prototype development, formation of a core team with complementary capabilities, and informal interactions. Many ventures are terminated during this phase, if they fail to get sufficient market traction.

During the emergent phase, successful firms experience "lead user" acceptance to signal future viability. Critical tasks include validating the business proposition, improving the prototype, forging collaborative partnerships and stimulating market demand. The organization may expand rapidly, and begins to outgrow its informal procedures and face-to-face interactions.

Ventures that do not experience market growth face a different reality. Some recalibrate their business trajectory and target different market segments. Others seek partners that augment their own capabilities. Some may sell their core technology to an established player. There are also many instances of the "living dead" (Bourgeois & Eisenhardt 1987); companies that would not survive without an artificial life support system; venture backers or angel investors who continue to fund their operations.

The ability to introduce strategic change and to redirect priorities may be relatively uncomplicated for a single-product company. The situation becomes more complex when a start-up reaches "adolescence". By this phase, a company may have introduced a second product line and would have typically broadened its sales efforts to cover additional market segments. It faces competition from both, new start-ups (at times its own spin-offs), as well as established companies that may be lured by growing market acceptance for pioneering products and demystification of new technologies. This competitive "pincer envelopment" can result in a loss of strategic focus and fragmentation of management attention.

Depending on the prevailing market and economic conditions, by this stage the typical adolescent company would have typically gone through a "liquidity event". This may be an Initial Public Offering (IPO) or an acquisition by another company. Organizationally, it has to digest its growth and instill a sense of uniformity and discipline. Informal procedures give way to more formal processes. The founding team may have been augmented or replaced by professional managers. While some members of the original team may choose to stay, it is unlikely that they retain their original power and influence. Some may have "burnt out" from the earlier years of "100 hour weeks"; others may simply be unable to cope with new managerial (rather than technical) challenges, or may want to pursue other interests, especially when their financial goals have been realized.

When it reaches the established phase of an "agile giant", a technology firm would have consolidated its position, and diversified into related businesses. This does not mean that it has a guaranteed future. Many have to reposition and reinvent themselves to address emerging market needs, as indicated by the

HP-Compaq merger, Adobe's acquisition of Macromedia, Apple's reinvention as a consumer electronics company, or Intel's exit from the memory business. However, in general, established technology firms are viewed as significant industry players.

Evolution through each stage depends on several factors: industry growth rates, market acceptance of new technologies, managerial competence, luck, and timing. The challenge is especially complex because of compressed time frames, steep oscillation in growth rates, quick emergence of global customers and competitors, rapid evolution of technological know-how, short product and market life cycles, and high expectations of knowledge workers.

Close physical proximity between different high tech companies is a critical success factor in Silicon Valley. It provides opportunities for spin-offs, cross-fertilization, and the creation of flexible partnering arrangements. Moreover, pioneering products and services do not develop in a vacuum, or in isolation from the user community. The diverse range of technology companies and the presence of various industry clusters means that the ecosystem hosts early adopters and lead users of new products and services. These players provide the crucial early feedback and help recalibrate the design features and market positioning of new products and services. They test product feasibility and usability so that engineering and marketing plans can be fine-tuned for later introduction into the broader mainstream market.

3.3.4 The Knowledge Lubricants

Hatching a technology venture is a complex process requiring the contribution of several specialists. However, a young start-up cannot afford to recruit all the experts, even when their expertise is needed urgently. In many technology sectors, product life cycles are short and windows of market opportunity are narrow. A crucial feature of the Silicon Valley ecosystem is the presence of a sophisticated service infrastructure of complementary specialists. They provide the necessary "lubrication" to get a new venture off the ground. They enable startups to focus on their chosen steeple of expertise, rather than dissipate their energies across a broad range of support activities. Lawyers, accountants, market researchers, headhunters, real estate brokers, technical advisors, among others, provide variable, specialist expertise, as and when needed.

Contract manufacturing services are available to develop prototypes, or to engage in high volume or "peak load" manufacturing of sub-systems and finished goods. Specialized public relations firms provide assistance with strategic marketing, product packaging, trade shows, company logos and other collateral. Accounting and law firms have specialized technology practices. Executive search firms scan for new talent and help augment management teams of growing ventures.

Real-estate firms have expertise in the provision of facilities, especially designed for high technology firms. For example, some may require clean rooms or highly purified water supplies.

Law firms play a crucial role in the creation of new ventures.[9] A handful of prominent law partnerships have grown in Silicon Valley by specializing in high technology services. They undertake several tasks, including initial incorporation and company name search, stock allocations, patent filings, alliance and acquisition agreements, preparation of public offering prospectus, SEC filings, and litigation support.

Typically, investors collaborate closely with law firms during several rounds of financing. A new start-up may be offered favorable fee structures, in the hope that as it grows, it would need substantial legal assistance and can pay accordingly. Senior partners typically forge long-standing relationships with the venture capital community and refer entrepreneurs to venture capitalists who have expertise or prior experience with a specific type of venture, a business category, or a vertical industry.

In summary, the "lubricants" are a critical component of the ecosystem and provide a broad range of complementary services. If a start-up needs to prototype an integrated circuit to test a new design, it can be fabricated in a matter of days; if it needs a booth for a trade show, it can be put together over a weekend; if it requires specialized advice, it can be provided by a phone call.

3.4 The Ecosystem's "Climate"

Just as species in a biological ecosystem share a common climate, so do the various building blocks of the Silicon Valley ecosystem. We use the term "climate" to refer to operating norms and ground rules that characterize common practices within the ecosystem. Whereas the building blocks described earlier are analogous to the "anatomy" of the ecosystem, the "climate" reflects its "personality". A cumulative result of historical precedents, successful business recipes, and legendary role models, these norms are about the business of technology venturing and the rules by which the game is played.

The ecosystem's climatic conditions are critical in understanding core processes that enable the ecosystem to adapt to new realities. As is the case with changing seasons in a natural ecosystem, Silicon Valley's climate is subject to continuous ebbs and flows; sometimes weather patterns can be predicted; other times they evolve unexpectedly. The following section describes broad "climatic conditions" that we have observed over time and that we believe characterize the ecosystem's modus operandi.

[9] For additional details, see Suchman (2000).

3.4.1 Goal-Driven Work Ethic and Eternal Optimism

A critical ingredient of the Silicon Valley ecosystem is the pioneering spirit and the relentless work ethic. The entrepreneurial culture was initially born out of a Californian history of pioneers making the perilous journey over the Rocky Mountains, coupled with the legacy of the Gold Rush.[10] As a result, Silicon Valley's cultural DNA is characterized by hard work, goal-driven action, and focused specialization.

After World War II, many ex-servicemen moved to the Bay area, encouraged and subsidized to attend local universities and to undertake further education. This development provided an educated and disciplined workforce for the early-generation companies, such as Hewlett Packard, Varian, Fairchild, Watkins Johnson and Lockheed. With the growing strategic importance of the Pacific Rim and the increasing technological intensity of the "Cold War", the educated GI's provided a disciplined and eager workforce that helped build many Valley companies during the 1950's and the 1960s. As this talent pool matured and rose to executive positions, the culture of many of the early pioneers was infused with strong work ethic, coupled with discipline and integrity.

This generation was later augmented by troops returning first from Korea, and later from Vietnam. Ironically the contrast between this "work hard/play hard" lifestyle was brought into sharp focus when contrasted with the rise of the "Hippy" movement in San Francisco during the late 60s and the 70s. Initially, the two worlds collided, but, over time, the two ends of the generational spectrum gradually coalesced.[11] We suggest that the fusion of the two worlds has played a critical role in forging the disciplined, yet creative, spirit of Silicon Valley.[12]

Historically, Silicon Valley entrepreneurs have exhibited many of the qualities of the early pioneers. They have taken enormous risks, innovated in areas that many said could not be done, worked long hours over extended time frames, showed passionate commitment to their ventures, and even suffered personal problems, while developing a product or building an enterprise.

This is not to suggest that all entrepreneurs in Silicon Valley are so passionate about their ventures that generating wealth is not on their radar screen. Indeed, attitudes towards wealth generation changed considerably during the Internet boom years, with the influx of a younger generation into the area. Financial targets and a quick "exit strategy" became the critical motivational drivers. However, if financial rewards were the only or the ultimate goal, it would be difficult to explain the

[10] See Kotkin and Grabowicz (1982)

[11] When Remedy, an enterprise software company in the helpdesk business, took its public offering road show to Wall Street and the City of London, the theme from Led Zeppelin song "Stairway to Heaven" was used as incidental music.

[12] This blending of dual cultures is underscored by some of the anecdotal observations we have heard from long-standing Valley entrepreneurs. They describe effective teams as a combination of the "suits" and the "cowboys".

phenomenon of "serial entrepreneurs". It does suggest, however, that those who have become legends in Silicon Valley, or who are inspirational role models, do exhibit "passionate" qualities. Their primary goal is not simply financial gain. There are strong emotional and intellectual drivers as well.

3.4.2 Limited "Safety Net" and Minimal "Life Support System"

Silicon Valley is truly a Darwinian ecosystem. There are no safety nets in that "only the fit survive". In this context, fitness is about competence, intelligence, adaptability and initiative, as well as prudent timing and luck. Fitness applies to both, individuals as well as enterprises, and can be assessed in terms of how well individual skills and capabilities, as well as enterprise products and services, match emerging opportunities.

A limited life support system means that nothing can be sustained artificially for long. This climatic condition, while brutal at times, can also facilitate rapid adaptation. For example, the high cost of living in the area has led many companies to move, initially low-skilled jobs, out of Silicon Valley to other locations and countries. In recent years, even core activities have moved offshore to countries such as India, China and Eastern Europe, where technical talent is cheaper and readily available.

There has also been a major shift in patterns of "cluster employment", reflecting market realities and changing conditions. According to 2003 Index of Joint Venture Silicon Valley, during 1992-2001, employment in defense and aerospace fell by 8%, reflecting reduced levels of defense expenditure after the end of the Cold War, while employment in software increased from 7% to 21%. By contrast, the number of jobs in clean tech and "green' businesses grew by 23% during 2005-2007.[13]

Another feature of the adaptation process, boosted by a limited life support system, is the "swarm effect". Just like bees around honey, investors and entrepreneurs throng around the latest new "category". This swarm effect ramps up experimentation rather quickly. However, since there are no safety nets, entrepreneurs and investors also "stampede" away from failed concepts and recipes. So if an idea goes out of favor, or does not pay off as initially promised, its demise is rather swift.

The same principle also applies to new ventures. If a venture is no longer viable, disengagement can be measured in terms of weeks, not months or years. By the same token, if something happens to change the prospects of an out-of-favor technology or a business concept, especially if justified by tangible market evidence, investors move back into the field rather quickly. The emphasis is on pragmatism or on "what works", rather than on idealism or "what should work".

[13] Source: Joint Venture Silicon Valley 2008 Index.

A limited "life support system", combined with pragmatism, is a critical catalyst for adaptation. This spirit is further reinforced by the success of "Davids" versus "Goliaths", the collapse of over-funded start-ups that have a great deal of initial credibility. It is also reflected in the dynamic evolution of "large companies". For example, as indicated in Table 5, approximately half the entities listed as the "forty largest technology" firms twenty years ago, no longer exist. Indeed "only four firms on the 2002 list are survivors from the 1982 list. More than half of the 2002 top firms were not even founded in 1982. Each year's list, on average, includes 23 new firms."[14]

1982	2002	2007
Hewlett Packard	Hewlett Packard	Hewlett Packard
National Semiconductor	Intel	Intel
Intel	Cisco	Cisco
Memorex	Sun	Apple
Varian	Solectron	Oracle
Environtech	Oracle	Google
Ampex	Agilent	Sun Microsystems
Raychem	Applied Materials	Sanmina-SCI
Amdahl	Apple	Applied Materials
Tymshare	Seagate	Calpine
AMD	AMD	eBay
Rolm	Sanmina-SCI	Synnex
Four Phase Systems	JDS Uniphase	Yahoo
Cooper Labs	3Com	Franklin Resources
Intersil	LSI Logic	AMD
SRI International	Maxtor	Symantec
Spectraphysics	National Semiconductor	Agilent
American Microsystems	KLA Tencor	Robert Half Int'l
Watkins Johnson	Atmel	Con-Way
Qume	SGI	Gilead Sciences
Measurex	Bell Microproducts	Nvidia
Tandem	Siebel	Bell Microproducts

[14] Source: Zhang 2003, P. 6: 1982 & 2002 data, Zhang 2003; 2007 Data from The San Jose Mercury News, Silicon Valley 150, April 11, 2008.

1982	2002	2007
Plantronics	Xilinx	SanDisk
Monolithic	Maxim Integrated	Adobe Systems
URS	Palm	Network Appliance
Tab Products	Lam Research	Electronic Arts
Siliconix	Quantum	Intuit
Dysan	Altera	Juniper Networks
Racal-Vadic	Electronic Arts	KLA-Tencor
Triad Systems	Cypress Semiconductor	Granite Construction
Xidex	Cadence Design	Lam Research
Avantek	Adobe Systems	LSI
Siltec	Intuit	Spansion
Quadrrex	Veritas Software	Maxim Integrated
Coherent	Novellus Systems	National Semiconductor
Verbatim	Yahoo	Varian Medical Systems
Anderson-Jacobson	Network Appliance	Xilinx

Table 5. Top twenty firms in Silicon Valley, 1982 and 2002 (Source Zhang 2003); 2007 Data from The San Jose Mercury News, Silicon Valley 150, April 11, 2008

3.4.3 Collaborative Partnerships and Recombinant Innovations

The Silicon Valley ecosystem nurtures collaborative relationships amongst specialized enterprises. Collectively, the groupings of knowledge originators, hatcheries, lubricants, and generators, provide "meta" flexibility at the level of the ecosystem. This is largely achieved through a process of "interlinked specialization and complementary collaboration"[15], Each firm focuses on what it does best and leverages others' for complementary activities. For example, a start-up can focus on technical design, and use other entities for prototype development, market research, public relations, advertising, and staffing. Established firms acquire young companies with breakthrough innovations, as indicated by Cisco's growth-by-acquisition strategy during the 1990s. Mid-sized adolescents become a distribution channel for emerging start-ups.

[15] The notion of "diverse specialization" was first discussed by Piore and Sabel (1984).

Collaborative partnerships are the lifeblood of the ecosystem. They are forged between individuals when they coalesce into entrepreneurial founding teams; venture capitalists forge alliances, in the form of a syndicate, to co-invest in new ventures. Alliances are forged between established and emerging firms for manufacturing, development, or distribution purposes, and with contractors, vendors, and outsourcers for providing complementary capabilities.[16] These arrangements are helpful for small start-ups, hoping to penetrate challenging markets, or for larger firms, intending to fill their pipelines and maintain the flow of innovative products.

The innovation process reflects this emphasis on collaboration and complementaries. It is as much about blending and combining, through collaborative processes, as it is about breakthroughs in new fields. Often an end-of-life technology can be refreshed and augmented by the addition of something new. Or something that was only possible to do in a given domain can be applied to another.

Consider, for example, how removable Winchester disk drives leveraged the technology used in floppy disk drives and enhanced input/output controllers in order to upgrade to non-sealed units, first with Syquest cartridges, and later with Zip drives; how Google's founders used data mining technology to develop a search engine; or how ROLM's founding team pioneered the digital PBX by applying minicomputer technology to the telecommunications equipment business.

3.5 Super-Flexibility and the Ecosystem

Silicon Valley's operating norms and entrepreneurial "climate" impacts the dynamics of the adaptation process. It is not sufficient to create the anatomical building blocks, without considering the climate's impact on the ecosystem. Having venture capital, without the ability to "pull the plug" at the right time, is not conducive to creating viable, new ventures. Similarly, having world-class universities and research laboratories, without developing an open attitude to partnering and information sharing, does not lead to the generation of a critical mass of innovative ventures. Silicon Valley should be understood in the context of both, its anatomy as well as its personality. Taken as a whole, it provides an innovative laboratory for studying the process of dynamic adaptation.

[16] Global alliances have been a historic feature of Silicon Valley. For example, The now-defunct personal communications start-up, EO, had a number of global partners, including AT&T, Matsushita, Marubeni, amongst others, only 18 months into the venture's life-cycle, before being acquired by AT&T. 3DO, a multimedia firm founded by Trip Hawkins, the founder of Electronic Arts, was initially a joint venture between Time Warner, Matsushita and Electronic Arts. Similarly, General Magic, the personal communications software company and an Apple spin-off, was initially forged through an alliance between Apple, AT&T, Philips and Sony. Quantum Corporation, the disk drive firm, allied itself with Matsushita, as its manufacturing partner, during the 1980s. Auspex Systems, the file server company, forged an alliance with Fuji-Xerox in its formative years, involving both investments and distribution agreements.

The constellation of knowledge originators, hatcheries, generators and lubricants in Silicon Valley, characterize a dynamic ecosystem of independent, yet complementary, entities, communities, and cultures. The ecosystem is super-flexible by being robust as well as versatile. It is able to withstand turbulence, but can also transform and adapt itself. Since each building block is modular and autonomous, the ecosystem can withstand shocks and perturbations. If a venture fails, or a "category" goes out of favor, it is not necessarily detrimental for the entire ecosystem. The ecosystem is versatile in that new competencies can be quickly generated through the process of collaboration and cross-fertilization.

Silicon Valley's knowledge enterprises operate in a fluid, loosely-coupled, dynamic ecosystem. The ecosystem has specialized, modular building blocks, and a shared, common climate. Its distinctive "macro-climate" is characterized by "meritocratic norms", limited safety nets, transparent *de facto* standards, open feedback loops, interdependent relationships, and a dual focus on competition and collaboration. Distinctive "micro-climates" coexist within the broader "macro-climate", providing additional stimuli to adapt to unique industry and enterprise norms. The ecosystem, we argue, provides the "meta" context within which entrepreneurial firms can dynamically adapt to new realities.

Silicon Valley has generated a critical mass of knowledge enterprises, whose innovative products and solutions have transformed the global economy. The ecosystem provides an anchor of stability within which incumbent firms and new start-ups can flourish and become a source of innovation and employment. Yet it adapts to new realities through a process of "recycling" where failed ventures and terminated initiatives are re-configured, re-blended, and ultimately re-packaged in order to adapt to emerging challenges and new opportunities. The dynamic concept of "recycling", our first action principle, will be explored in Chapter 4.