Clustering in ICT: From Route 128 to Silicon Valley, from DEC to Google, from Hardware to Content

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ABSTRACT AND KEYWORDS	
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Clustering in ICT:

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ABSTRACT

One of the pioneers in academic entrepreneurship and high-tech clustering is MIT and the Route 128/Boston region. Silicon Valley centered around Stanford University was originally a fast follower and only later emerged as a scientific and industrial hotspot. Several technology and innovation waves, have shaped Silicon Valley over all the years. The initial regional success of Silicon Valley started with electro-technical instruments and defense applications in the 1940s and 1950s (represented by companies as Litton Engineering and Hewlett & Packard). In the 1960s and 1970s, the region became a national and international leader in the design and production of integrated circuit and computer chips, and as such became identified as Silicon Valley (e.g. Fairchild Semiconductor, and Intel). In the 1970s and 1980s, Silicon Valley capitalised further on the development, manufacturing and sales of the personal computer and workstations (e.g. Apple, Silicon Graphics and SUN), followed by the proliferation of telecommunications and Internet technologies in the 1990s (e.g. Cisco, 3Com) and Internet-based applications and info-mediation services (e.g. Yahoo, Google) in the late 1990s and early 2000s. When the external and/or internal conditions of its key industries change, Silicon Valley seemed to have an innate capability to restructure itself by a rapid and frequent reshuffling of people, competencies, resources and firms. To characterise the demise of one firm leading, directly or indirectly, to the formation of another and the reconfiguration of business models and product offerings by the larger companies in emerging industries, Bahrami & Evans (2000) introduced the term `flexible recycling.' This dynamic process of learning by doing, failing and recombining (i.e. allowing new firms to rise from the ashes of failed enterprises) is one of the key factors underlying the dominance of Silicon Valley in the new economy.

INTRODUCTION

> *In the beginning, there was a garage in northern California. And the garage – plus two nerds – begat the personal computer. And it was good. In fact, it was a best thing, the first best thing. And the two nerds became rich and multiplied. And the first best thing begat a faster slicker machine – the next best thing – and it begat the next and the next and so on and on until, one day, the best things begat Silicon Valley* (Dillon 1996: dust-jacket).

Silicon Valley is the ideal version of a dynamic techno-industrial region and as such it has been widely emulated, both within and outside the US (Rosenberg 2002; Bresnahan & Gambardella 2004). Another remarkable achievement is the ease and speed with which Silicon Valley manages to adapt to changing circumstances.

Originally Santa Clara Valley was a rural area with small-scale horticulture (i.e. the growing of all kind of fruits and vegetables); now this valley has been transformed into a *high-tech region*, characterised by extensive technology and office parks, urban areas, large-scale shopping centres, connected by a close-knit network of highways. Some authors go even further and interpret the making of the booming hotspot in North California as a 20th version of the *Renaissance* (Winslow 1995). A key role in developing these high technologies in the Valley was played by Stanford University, continuously seeking to commercialise new knowledge and innovations through contract research and promoting start-up and spin-off companies. Silicon Valley has become a magnet attracting talent from all over the world with open and flexible labour markets characterized by task rotation, horizontal mobility, and information for a continuous fermentation of new ideas and stimulating new techno-industrial and organizational challenges (Hyde 2003). Furthermore, entrepreneurial engineers and managers leave their established companies to start for themselves (in the 1960s), leading technology firms have established themselves in this dynamic cluster in order to draw from an emerging concentration of talented people (in the 1960s and 1970s), and also venture capital firms established themselves in the heart of Silicon Valley that was to become a hot spot for talent, creativity, innovativeness and high-impact venturing.

The rural Santa Clara Valley has become the techno-industrial hotspot Silicon Valley, where initially the focus was on the design and production of semiconductors (in the 1960s and 1970s), and later on the manufacturing of personal computers, network technologies and workstations (in the 1980s and 1990s), and eventually moving towards all kind of Internet applications and multimedia (late 1990s till today). Silicon Valley, or more appropriately the Bay Area, is also one of the leading global centres of expertise in the field of biotechnology (Zhang & Patel 2005). This dominance started with the first demonstration of gene cloning and splicing (recombinant DNA) in the early 1970s by Stanley Cohen of the Stanford Medical School and Herbert Boyer of the University of California San Francisco. The subsequent patents on gene cloning and gene splicing made that the two North-Californian universities big earners of royalties and turned Genentech, set up by the scientist Boyer and the venture capitalist Robert Swanson of Kleiner & Perkins in 1976/77 and located in the Southern parts of San Francisco, into a successful and major developer of human protein and human insulin. Other leading Silicon Valley and Bay Area companies that were among the pioneers of the biotechnology industry are Cetus-Chiron, Affymetrix, and Gilead Sciences.

Long before the rise of Silicon Valley, Route 128 around Boston in Massachusetts played a pioneering role in the clustering of information and communication technology companies. Massachusetts is among the leading technology states, in terms of patents per capita, invention disclosures, technology licenses issued, venture capital and the number of initial public offerings; diversified employment and diverse industrial base (Lampe, 1988: Rosegrant & Lampe, 1992). Furthermore, the Boston area has among the highest concentration of colleges and universities, research institutes and hospitals in the world. In addition to Massachusetts Institute of Technology (MIT) and Harvard University, the region has other important universities, such as Northeastern, Babson College, Boston University, Brandeis, University of Massachusetts, and Tufts University. In the domain of science and technology development and biomedical research, the Boston region has internationally renowned R&D laboratories at its disposal, such as Draper, Lincoln, Mitre Corporation, the Whitehead Institute, and the Dana-Farber Institute, and the leading combined teaching and research hospitals Brigham and Women's Hospital and Massachusetts General Hospital (both affiliated with Harvard Medical School). With such a deep and diverse knowledge base it is not without surprise that the Route 128 region is also leading in the field of biotechnology, both in technology and market development with flagship firms such as Seragen, Repligen, Biogen, Genzyme, and Cambridge Bio having the greater Boston area as their home base. As such, MIT and Harvard University, together with their spin-off firms and R&D affiliations were among the global pioneers in modern academic entrepreneurship and high-technology cluster development (Etzkowitz, 2002; Cruikshank, 2005). In the first half of the 20th century, MIT served as a model for Stanford University and other research universities with regard to working together with companies in the area of education and research, among other things through apprenticeships, business consultancy, contract research, spin-off creation and the use of venture capital. The MIT/Route 128 cluster has always depended heavily on the defense policy of the American government. In 1962, for instance, government purchases made up about half of the turnover of the local businesses in the region. MIT, and its specialised research laboratories (like the Draper & Lincoln Labs), has been part of the military-industrial complex. The big defence and aerospace contracts were awarded to MIT-related firms like DEC, Raytheon, Data General, Prime and EG&G.

Although MIT originally served as a role model for Stanford, in recent decades the situation has been reversed: Stanford University was among the first in the world to establish an independent contract research organisation (Stanford Research Institute in 1946, later renamed as SRI) and a science and technology park (Stanford Industrial Park in 1951, later renamed as Stanford Research park). In the 1950s and 1960s, economic gravity shifted to the West Coast and due to the catch-up efforts of Stanford University, supported by the University of California Berkeley, and the techno-industrial achievements of its affiliated companies and institutions (e.g. HP, Intel, XEROX, SRI), Silicon Valley had the cutting edge from the 1970s onwards. This chapter starts with shedding a light on the pioneer in academic entrepreneurship and high-tech clustering, namely MIT and the Route 128/Boston region. Then the attention shifts to the fast follower Silicon Valley and its emergence as a scientific and industrial hotspot. Several technology and innovation waves, have shaped Silicon Valley over all the years; the dominant ones are identified below and will be discussed subsequently (see figure 1):

- the initial regional success of Silicon Valley started with electro-technical instruments and defense applications in the 1940s and 1950s (represented by companies as Litton Engineering and Hewlett & Packard);
- in the 1960s and 1970s, the region became a national and international leader in the design and production of integrated circuit and computer chips, and as such became identified as Silicon Valley (e.g. Fairchild Semiconductor, and Intel);
- in the 1970s and 1980s, Silicon Valley capitalised further on the development, manufacturing and sales of the personal computer and workstations (e.g. Apple, Silicon Graphics and SUN);
- and followed by the proliferation of telecommunications and Internet technologies in the 1990s (e.g. Cisco, 3Com) and Internet-based applications and info-mediation services (e.g. Yahoo, Google) in the late 1990s and early 2000s.

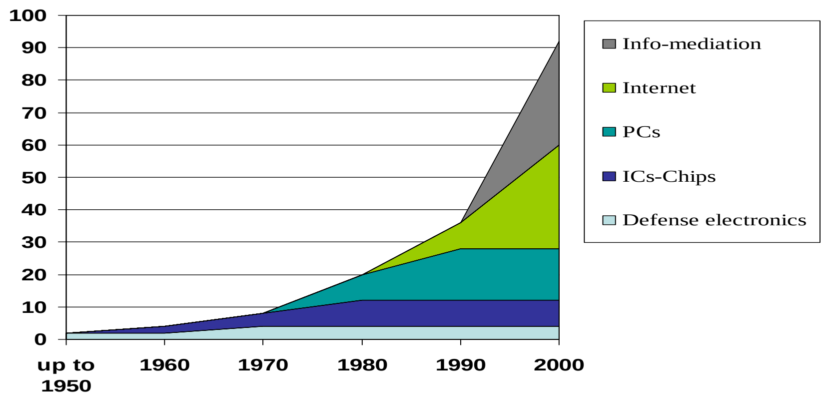

Figure 1: The growth of Silicon Valley (1950-2000) (based on Joint Venture 2001)

When the external and/or internal conditions of its key industries change, Silicon Valley seemed to have an innate capability to restructure itself by a rapid and frequent reshuffling of people, competencies, resources and firms. To characterise the demise of one firm leading, directly or indirectly, to the formation of another and the reconfiguration of business models and product offerings by the larger companies in emerging industries, Bahrami & Evans (2000) introduced the term `flexible recycling. This dynamic process of learning by doing, failing and recombining (i.e. allowing new firms to rise from the ashes of failed enterprises) is one of the key factors underlying the dominance of Silicon Valley in the new economy. A key concept in the emergence and evolution of new industries, like semiconductors and computing, is the notion of ‘genealogy maps’ providing relational information on founders of companies and the previous company affiliation of the founders. Especially, in an environment with a high degree of techno-industrial dynamics, volatility and entrepreneurialism, we can chart a *genealogy* of spin-off firms from source organisations, like universities and corporate laboratories, created by entrepreneurial engineers and managers setting up their own shop and established organizations spawning out project teams and established as independent entities. Examples of spin-off formation, repeat (or serial) entrepreneurship and corporate divestitures are given in this chapter through the genealogy charts of the spin-off firms of MIT and Stanford, and the leading Silicon Valley R&D laboratory of XEROX PARC and the pioneering semiconductor company Fairchild.

THE PIONEER: MIT'S ROUTE 128 IN GREATER BOSTON (NEW ENGLAND)

Route 128 refers to the region along the Yankee Division Highway (Route 128, Interstate 95), some 14 miles of highway to the west of Boston, Massachusetts. Boston has an age-old industrial tradition: first textile, guns and machine tools, after that automobiles and electrotechnical instruments, and then (mini)computers and information systems. The region's core institute is the Massachusetts Institute of Technology (MIT), which was established in 1861. MIT was founded with assistance from a 30% share of the state of Massachusetts land grant policy (under the Morill Act federal lands were provided to each state to support the development of institutions of higher education for the benefit of agriculture, mining, and manufacturing). MIT played a pioneering role in stimulating 'academic' entrepreneurship and technology transfer (Etzkowitz, 2002). For instance, scientists and doctoral students were encouraged by the MIT-directors to exploit the research results commercially, do regular (part-time) consultancy activities and to set up their own companies. Early spin-offs of MIT were the consulting and engineering firm of Stone Webster and Arthur D. Little at the end of the 19th century. In the early 20th century, MIT gave birth to, for instance, Raytheon (founded in 1922 as the American Appliance Company by the then MIT professor Vannevar Bush), EG&G (founded in 1933 by MIT professor Harold Edgerton and his associates Germeshausen and Grier) and Polaroid (founded in 1937 by former MIT researcher Edwin Land).

As an institution, MIT placed great value on the social and/or industrial commitment of education and research, and on carrying out contract research for (local) businesses. MIT always kept close links with industry, especially with large companies like General Electric, Eastman Kodak and Dupont. To this end, a special *Technology Plan* was developed in 1918, in which industrial sponsors contributed ideas and resources for fundamental and applied research. In the 1920's, a special *Division of Industrial Cooperation and Research* was set up to maintain research contacts and to acquire and carry out contract research for companies. Later, the Technology Plan was integrated into the Contract Research Division, which in turn saw its name changed to *the Office of Sponsored Projects*. After the industrial slump in the 1930's, large-scale government investments in new military technology and defence industry during the Second World War led to a revival of the New England

and Massachusetts economy. In that period MIT became the country's leading research centre. MIT laboratories received $ 330 million, one third of all the assignments of the *Federal Office for Scientific Research and Development (OSRD)*, possibly in part thanks to its director Vannevar Bush, former professor and Vice President of MIT and co-founder of military equipment supplier Raytheon. The local industry also benefited. Thanks to military orders during the Second World War, Raytheon's turnover grew from $ 3 million to $ 173 million. The so-called *Research Row*, with the laboratories of MIT, Harvard University and industrial laboratories located to each other almost within walking distance, formed an unparalleled intellectual and technological labour pool at the end of the Second World War.

Karl Taylor Compton, MIT's President between 1930 and 1948, ensured that the (potential) academic entrepreneurs of MIT were given easier access to venture capital. While Raytheon was founded in the 1920's with financial support from banker J.P. Morgan, local insurance companies and wealthy Bostonians, in 1946 Compton, together with Harvard colleague General Georges Doriot (Professor Industrial Management) and MIT alumni, created the first venture capital fund, i.e. American Research and Development (ARD). In the early years of ARD's existence MIT's influence was still big (via a direct investment in the fund and representation of the faculty directors on the Council for Scientific Advice). Later MIT reduced its financial and organisational commitments. ARD's first major investments were in High Voltage Engineering, Ionics, Tracerlab and Digital Equipment Corporation. Later, various venture capital companies emerged from ARD, the most important ones being Boston Capital, Palmer, Charles River Partnership and Morgan-Holland (Tödtling 1994).

The success of the industry from the Route 128 region led to a surplus of capital, while government contracts kept coming. In the forties and fifties MIT founded a number of important research laboratories that are still international leaders. The Radiation Laboratory (which was later split up into the Research Laboratory for Electronics and the independent Air Force Cambridge Research Laboratory) and the Instrumentation Laboratory (which in 1973 became independent and was renamed the Charles Stark Draper Lab) played an important role in the development of radar and navigation systems. In 1951, the Lincoln Laboratory was founded, among other things for the development of high-speed digital data processors for military applications. In terms of financing, the Lincoln Lab has always been heavily dependent on the defence authorities. One of the spin-offs of the Lincoln Labs was the MITRE Corporation, founded in 1958, which had a special responsibility for carrying out contract research for the Federal Government and for designing and managing defence systems (Hughes 1998).

In the 1950's, Route 128 was the home base of various leading semiconductor manufacturers: e.g. Sylvania, Transitron, RCA and Western Electric. Also the first minicomputer companies were founded, initially for a specific purpose (Ceruzzi 1998). Wang Laboratories (founded by An Wang as a spin-off of Harvard University's Computer Lab) started in 1951, and initially focused on calculators and later on office automation and word processing. Ken Olsen, involved in the Lincoln Lab in the deployment of advanced computers in an air defence system (the combined *SAGE Air defence system* and the *Whirlwind computer project*), in 1957, together with partner Harlan Anderson and with financial support from ARD ($ 70,000), founded Digital Equipment Corporation (Roberts 1991). Within DEC Olsen and Anderson were looking for ways to make computers smaller and more versatile, and in 1959 this led to the first commercial *general-purpose* computer: the Programmed Data Processor (PDP)-1. In the sixties and seventies dozens of minicomputer firms were founded, often as spin-offs of existing companies. The successful entrepreneurs served as attractive role models to potential entrepreneurs. Well-known examples are Data General as a spin-off of DEC (1968) and Prime Computer as a spin-off of Honeywell (1972). The minicomputer industry emerged in parallel with the electronic industry and as such could utilise the available *job shops*. In the course of the 1970's, the quickly developing minicomputer industry led to a revival of the regions economy. The big computer manufacturers DEC, Data General, Wang, Honeywell and Prime dominated the regional economy and controlled at that time two-thirds of the world's minicomputer market. In 1977, DEC's turnover broke the $ 1 billion barrier, and in 1982 the company was the world's undisputed minicomputer champion with a 42% share (local competitor Data General had an 11% share) (Rogers & Larsen 1984: 238).

The dominant industrial system for the production of (mini)computers was to a large extent vertically integrated, with independently operating companies taking care of all the links in the computer's value chain. Rather, than outsourcing, companies like Data General and DEC manufactured their own internal components (e.g. semiconductors, keyboards, disk drives and screens). The technology companies of Route 128 have a quasi-hierarchical kind of entrepreneurship with a strong company loyalty which, according to Saxenian (1994), they have taken over from earlier generations of industrial enterprises. The social relations and dominant culture of New England are characterised by a tradition of cautiousness and frugality. Identity comes from the family and class to which one belongs. The social environment is formed by the 'extended' family of church, local schools, clubs, etc. The number of informal business and professional contacts between companies is limited. Stability and loyalty were valued more than experimenting and taking risks. This autarchic business culture, with, for instance, few spin-off companies, was stimulated by the ongoing dominance of military technological research and the production of defence parts that involved a certain degree of secrecy. Also, the companies opted in favour of proprietary products and systems as a way of keeping out the competition, rather than looking for fast innovation and dynamics by using open and non-exclusive standards. With these exclusive products customers would have to make large investments, if they were to switch suppliers. Even the venture capital sector in

Boston was conservative, and as such it was dominated by bankers rather than (former) entrepreneurs.

In the seventies and eighties, MIT, with the knowledge gathered about computer time sharing and man-machine interface in the SAGE and MAC projects of the fifties and sixties, together with Harvard University, MIT spin-off Bolt Beranek & Newman (BBN) and computer researchers from California (UCLA, Stanford and RAND), gave an enormous boost to the creation of what would evolve into the Internet (Hafner & Lyon 1996; Hughes 1998). First, the Lincoln Lab, and later the Laboratory for Computer Science (LCS), which was founded in 1964, played an important role in the invention and further development of the main components of the advanced computer system of the Internet, such as, the IMP (Interface Message Processor: a router *avant la lettre*), TCP/IP network protocol and RSA encryption technology (Hughes 1998). As with numerous other MIT institutes, the contract research that was carried out within LCS has led to a number of commercial spin-offs, for example: Computek (founded in 1968 by LCS researcher Dertouzos), Infocom (co-founded in 1979 by LCS director Licklider), and RSA Data Security (founded in 1983 by LCS researchers Rivest, Shamir and Adleman).

The minicomputer manufacturers of Route 128 quickly lost ground to the manufacturers of the fast-emerging PC's and workstations in Silicon Valley. Fast technological developments and dynamic market changes favour an open and entrepreneurial culture and industrial system that is based on flexible production networks and on encouraging experimentation and open innovation, such as in Silicon Valley. In itself the industrial system of Route 128, based as it is on vertically integrated companies operating (relatively) independently from each other and following a more closed innovation model, does not have to be a problem, as long there is no enormous growth and as long as the technological developments can be predicted and planned. The speedy and revolutionary developments in network and Internet technology, however, demand an open strategy and non-exclusive systems, allowing many parties to contribute and to specialise in certain components and (sub)products. Something what cannot be found in the Boston, but can be found in the Bay Area, although MIT remains to play an important role. As a research and education centre, like in the past, MIT keeps churning out highly educated engineers and highly motivated technology entrepreneurs (Roberts 1991). Its record is so strong that it remains to be a breeding ground and a kind of nursery case for Silicon Valley entrepreneurs (see figure 2).

THE FAST FOLLOWER: STANFORD'S SILICON VALLEY IN THE SAN FRANCISCO/SAN JOSE AREA

Silicon Valley was given its name by journalist Don Hoefler, who in 1971 wrote a number of articles about the semiconductor industry around Palo Alto in *Electronic News*. The origin of the industrial area is considered to be the creation of Hewlett-Packard Company (HP) in 1939, which began in a small garage in Palo Alto, not far from Stanford University. Silicon Valley now contains a heterogeneous network of larger and smaller technology companies, leading universities and research institutes, and an infrastructure of venture capitalists, specialised law firms, consultancies and other service providers (project developers, marketers, equipment leasers). This network was developed and matured especially in the fifties. The foundations go back to the 19th century and the first quarter of the 20th century with the creation and growth of Stanford University, the establishment and evolution of Silicon Valley's first flagship firm 'Federal Telegraph (FT)' (with the help of Stanford University.

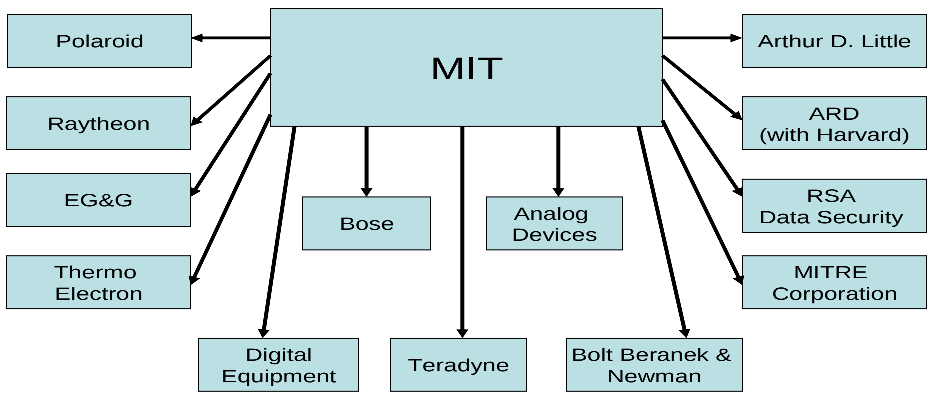

Figure 2: The genealogy of MIT

The history of Stanford University goes back to 1891, when the former governor, senator and entrepreneur (president of the Central Pacific Railroad) Leland Stanford Sr., founded a university in the memory of his son, who had died at an early age: the Leland Stanford Junior University. The location for this private university was Palo Alto, where the family owned a farm and over 3,000 hectares of land. Students of this new university were expected not only to be motivated by a desire for knowledge, but also to apply that knowledge in every day (business) life. A former graduate from Stanford, Frederick Terman, later professor and dean of the Engineering School and Chairman of the University became the godfather of Stanford spin-offs and of all those 'academic' entrepreneurs who after graduation were to start their own companies; when Hewlett and Packard had just set up their company he gave them some money (see figure 2). Inspired by the dynamics of the East Coast, Terman wanted to create a technological community between local businesses and Stanford University. After taking a course in electrical engineering at Stanford in the early 1920s, Terman seemed to have wound up in the MIT-Harvard network on the East Coast. He took a PhD with the afore-mentioned Professor Bush at MIT. However, during an attack of tuberculosis he decided to move back temporarily to sunny and pleasant California. He eventually decided to stay on the West Coast after he was appointed professor at the Engineering School and he was in a position to lead the new radio communication research laboratory at Stanford. Terman's stay in California was interrupted during the Second World War, when he was director of Harvard's Radio Research Laboratory. In Terman's view (who had clearly been influenced by his teacher Vannevar Bush) Stanford University, like MIT on the East Coast, should be a centre for applied research and for close cooperation between a (technical) university, specialised contract research organisations, innovative companies and joint R&D centres: *'Such a community is composed of industries using highly sophisticated technologies, together with a strong university that is sensitive to the creative activities of the surrounding industry. This pattern appears to be the wave of the future* (Terman quoted in Saxenian 1994: 22)'. In this context the Federal Government, to be more precise the Department of Defense, was also important: it needed supercomputers and later semiconductors, computer chips and network technologies.

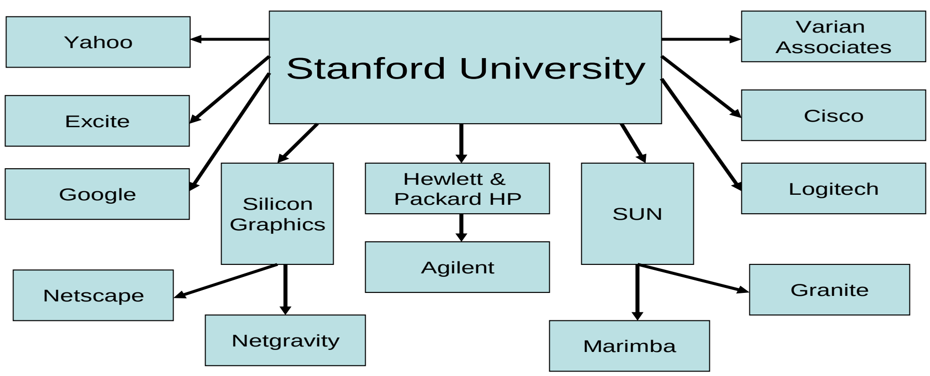

Figure 3: the Stanford connection

An important initiative in which Terman and a number of local entrepreneurs played a part was the creation, in 1946, of a special organisation within Stanford University to market technology and conduct contract research. In 1971, this Stanford Research Institute (SRI) became independent of Stanford University and was renamed SRI International. The research institute has a number of technological breakthroughs to its name, such as the inkjet printer, the modem and optical storage and scanning media. Terman was also closely involved in the commercial development of the large stretches of land that the Stanford heirs possessed. In his mind this provided an ideal opportunity for an R&D park close to the university. There were financial and strategic reasons for this. To have access to short-term funds and to be able to start up new projects in the future, Stanford University decided to lease part of the 3,000 hectare to the Stanford Shopping Center (which brought in $ 3 million a year). The creation of the Stanford Industrial Park in 1951, the first technology and science park in the world, in addition to having the above-mentioned financial reason, also had a strategic reason. Terman wanted to use the proceeds for a kind of 'fighting fund' to develop new activities on campus (Rogers & Larsen 1984: 35/36). The Industrial Park should become an attractive location for start-ups, specialised laboratories, offices and light production facilities of more established companies. In turn the university would not only have access to additional resources, it would also benefit from the investments and research plans of large and small technology companies. Lockheed, for example, moved its Missiles and Space Division to Sunnyvale and set up a special research laboratory, together with the university, on the Stanford Industrial Park. After welcoming its first tenants, Varian Associates, HP, Eastman Kodak and Lockheed, the technology park grew to 40 companies in 1960. Another institutional innovation Terman implemented was the creation of an Office of Technology Licensing & Intellectual Property, founded in 1970, which focused on the commercialisation of the inventions of university researchers, patent applications and the stimulation of royalty revenues.

Some FT employees started their own companies, just like Fairchild was to do almost 40 years later. In 1931, Jensen, Albertus and Pridham founded the audio-speaker company Magnavox, a company that is still well-known today. Another former Stanford student and FT employee was Charles Litton, who in 1932 established the still existing electronics company Litton Engineering Laboratories (after a wave of mergers, acquisitions and corporate restructuring, the company relocated to the Los Angeles area and re-established itself as a major defense contractor in 1953). In the 1930 and 1940s, Litton also became well-known as a stimulator of applied research and of innovations (by providing start-ups like Hewlett and Packard access to his laboratories) and as the animator of knowledge sharing and technology transfer for former Stanford students by organising seminars and discussions on applied research in his offices (Packard 1996). These seminars could be seen as the precursor of the sessions of the Homebrew Club, the computer enthusiasts club from the seventies. Another company in the Bay Area was the Ampex Corporation, which was founded in 1944 by Alex Poniatoff, the pioneer in the area of tape recording and radio antenna equipment. This company, became famous in the seventies when one of its employees, Nolan Bushnell, who was to become a pioneer in computer games, left the company to start a company called Atari.

The first generation of companies: from electrotechnical instruments to integrated circuits

In 1937, William Hewlett and David Packard were encouraged by Terman to produce and market their design of an audio-oscillator (Packard 1996). HP's first products, measuring and testing instruments, had been developed while Hewlett and

Packard were still students at Stanford's Electrical Engineering Department. Although the idea to market their knowledge and products came from themselves, Terman arranged a part-time job at the faculty for one of them and helped the company secure a $ 750 loan from a Palo Alto bank (in addition to lending them an additional $ 538 himself). Although the company was not unsuccessful, it was only after the Second World War that it started to grow. Through military contracts for electronic measuring and testing equipment and receivers, the company's turnover grew. HP is still one of the world's leading electronics companies. Over time the company has expanded its technology portfolio from measuring and testing equipment to components, computer and network equipment, printing equipment and medical products and systems. In 1977, Hewlett and Packard paid back the money that Terman had given them in 1938, by donating $ 9.2 million to Stanford University for the construction of the Terman Engineering Center. In 1999, the company announced a split: its former core activity, the development and sale of measuring and testing equipment, was made independent (to which purpose a new company, *Agilent Technologies*, was created, and its current core activities (computers, network and printing equipment and medical technologies) remained part of the new HP.

Despite having reached the respectable age of almost fifty and despite having expanded its scope, HP has tried to retain its innovative and entrepreneurial spirit through a participating and decentralised management style, known inside and outside the company as the *HP Way* (Packard 1996). This approach to work and management focuses on cooperation, effective project management and involvement from and by the entire organisation. Well-known elements of the HP Way are the use of team work, cross-functional integration, task forces and management-by-objectives. Also, HP was among the first companies to experiment with 'flextime', 'open storeroom' policy and workforce participation (via profit sharing and stock options. Over the years HP has always had a close connection with Stanford University. HP, for example, was one of the first tenants of the university's new technology and science park, Stanford Industrial Park. Also, together they developed a special (post)doctoral evening course at Stanford University for HP engineers, the *Honors Cooperative Program*.

Many high-tech companies at home and abroad have tried to emulate HP's success.The company was an inspiration for many Silicon Valley start-ups (think of the garages in the Bay Area as nurseries for innovation and entrepreneurship). However, there is one major difference between the first generation of Silicon Valley and the subsequent generations. Companies like Intel, Apple, Sun, Cisco, Oracle, Netscape, Google, PayPal, YouTube have (in part) grown as a result of an active involvement of venture capitalists (e.g. Arthur Rock, Kleiner & Perkins, etc.), recognised business angels (Markula at Apple) and successful entrepreneurs (Clark at Netscape). HP financed its growth from its own resources. Instead of borrowing money from banks or giving shares to formal and informal investors, Packard and

Hewlett chose to expand on the basis of their own resources and profits (Packard 1996).

In addition to HP, there were other (smaller) electronics companies from Northern California that benefited from the defence contracts during the war. However, they did so at a modest scale, because the lion's share of government investments stayed on the East Coast (Route 128/Boston). To change this state of affairs, 25 California-based companies founded the Western Electronics Manufacturers Association (WEMA). Later, when WEMA had become successful, and a larger share of government investments went to the West Coast, WEMA was incorporated into the American Eletctronics Agency (AEA). Thus, in 1964, Silicon Valley and the Los Angeles and San Diego area were awarded 36.5% and 47.5% respectively of the Federal Department of Defense and NASA contracts (Hall 1998: 433). Important customers for the various generations of electronics companies from Silicon Valley were the Ames Research Center (the aviation and aerospace research centre of the National Advisory Committee on Aeronautics and of NASA); Moffett Field Naval Air Station (later renamed Moffett Federal Base) (both located in Sunnyvale) and the Lawrence Livermore Laboratories (the research centre of the University of California). Attempting to increase cooperation between Stanford and the local industry was necessary to keep the gap in industrial development from increasing any further. The industrial activity around Stanford kept growing due to continuous military contracts. Thanks to the concentration of activity, knowledge and skills, and the friendly climate and natural beauty of the area, an increasing number of companies and research laboratories moved to the region. In the 1950s and 1960s, in the hay days of research labs, Lockheed, Westinghouse, Sylvania, Raytheon, ITT and IBM all set up research laboratories in the region.

IBM opened its first research laboratory in Northern California in San José in 1952, which would be responsible for applied research into computer data storage. This signified a commitment of Big Blue to Silicon Valley and its locally trained engineers and scientists. Unlike Xerox's research lab (see below), the IBM lab not only benefited the core enterprise, but also its former employees and spin-off companies. In the San José lab, for example, the random access memory system, the magnetic disk, the disk drive and the relational database technology were invented. These inventions have certainly not made IBM any poorer. Furthermore, IBM's staff included entrepreneurial people like Gene Amdahl and Alan Shugart, who later all set up several ICT companies of their own. Gene Amdahl, for instance, the main architect of IBM's 360 mainframe series, set up companies like Amdahl Corporation, Trilogy Systems and GRiD Systems Corporation. One of Amdahl's employees, Lawrence Ellison, together with former Ampex colleagues, in 1977 set up Oracle Systems. Another former IBM employee who set out on his own was Shugart, who founded Shugart Associates and later Seagate (both companies are manufacturers of disk drives and storage technology for desktop computers).

In 1970, Xerox Corporation set up its Palo Alto Research Centre (PARC). While the company's head office on the East Coast focused on the production of copying equipment, Xerox management wanted its West Coast branch to work on research and development of office automation. The list of experiments with new ICT applications and innovations that these scientists produced is impressive: personal computing, laser printer, easy-to-use word processing, desktop publishing, Ethernet/networking, open systems computing, graphical user interface, and bitmapping. However, Xerox never managed to reap the rewards of all these innovations. A number of the above-mentioned inventions was adopted and perfected by other companies (Apple with the computer mouse and icon-based computer operation, HP with the laser printer and SUN with open systems computing), or entrepreneurial researchers decided to set up their own companies to exploit the technologies they had developed (Adobe for desktop publishing and 3Com for ethernet/networking applications) (see figure 3). Xerox was unable to integrate these innovations in their existing business models (Chesbrough, 2003). In 2002 Xerox PARC was spun out as a separate company, although wholly owned by Xerox.

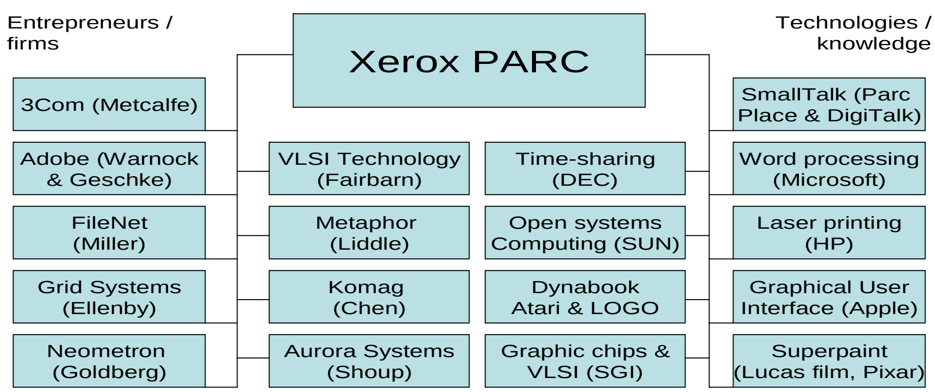

Figure 4: Xerox PARC's offspring (1979-1982)

The second generation of electronic companies: from computer chip to computer technology

It was especially the semiconductor sector that experienced tremendous growth, to become the dominant industry from the early 1970s onwards. That was also the reason to dub the area Silicon Valley, after its main raw material. One of the forerunners of the semiconductors was the transistor, which was invented in 1947 by the physicists Bardeen, Brattain and Shockley on the American East Coast in the

Bell/Western Electric laboratories in Murray Hill (New Jersey), for which they received the Nobel Prize for Physics nine years later. It would have made sense for the companies located in the region, like RCA, Sylvania and Bell/Western Electric, to have taken the initiative for further innovation and commercial exploitation. However, it was the periphery that was able to take the credit: transistors, semiconductors and integrated switches reached their commercial maturity in Silicon Valley (with Shockley Laboratories, Fairchild, Intel and National Semiconductor as the main manufacturers), Phoenix, Arizona (where Motorola was located) and Dallas, Texas (home of Texas Instruments). What is striking about this is that, like the Route 128 companies, Texas Instruments and Motorola cause far lesser external dynamics than the continuous flow of spin-offs created by the much more dynamic Silicon Valley companies (Hall 1998: 435/451). Apparently, the techno-industrial region of Silicon Valley is unique in its dynamic innovations, active knowledge transfer and strategic network activities (Saxenian 1994; 1999).

The choice of location of William Shockley and his research laboratory in what is now known as Silicon Valley was made more or less haphazardly. In the early fifties, Shockley had left AT&T's Bell Laboratories to start his own company. He had considered Boston as the located of his own company, with the backing of one of the local champions of Route 128, Raytheon. However, when Raytheon displayed little interest, Shockley went back to California, where he was given the financial support he needed to set up his business (from Shockley's former chemistry professor Beckman from the California Institute of Technology in Southern California). It started in 1955 with the foundation of the Shockley Semiconductor Laboratory in Mountain View, near Palo Alto. As one of the pioneers and experts in the field of transistor and semiconductor technology, it was easy for Shockley to appeal to highly qualified and ambitious researchers. He recruited a top team of young scientists and electronics specialists, and who to a certain extent were drawn by Shockley's reputation as a scientist and by the pleasant Palo Alto environment. Most of Shockley's people at some point became successful in the area of fundamental and applied research and/or high-tech entrepreneurship. Among Shockley's early employees were people like Eugene Kleiner (then coming from General Electric, later founder/partner at venture capitalist Kleiner & Perkins), Gordon Moore (then Johns Hopkins University, later Intel), Robert Noyce (then Philco-Ford, later Intel) and Jean Hoerni (then California Institute of Technology, later Fairchild and Amelco, Union Carbide Electronics and Intersil). Although they were impressed by his electronics expertise, his detailed management style and aversion to working solely with silicon annoyed people to such an extent that eight of the top engineers left Shockley's enterprise within two years after he had started.

In 1957, the eight engineers, later known as *The Traitorous Eight*, set up the semi-independent Fairchild Semiconductor with the help of the industrial sponsor Fairchild Camera & Instrumentation Corporation from New Jersey. Their leader was Robert Noyce, who in 1959, together with Jack Kilby of Texas Instruments, invented the integrated circuit. Since at that time there was hardly any venture capital available outside Boston and New York, the inventors had to depend on the inventiveness of New York investment banker Hayden Stone, who suggested Fairchild (Hall 1998: 436). Fairchild invested in the new electronics company on condition that the parent company could take over the shares of the daughter company's founders for three million dollars in case the new company were to make a profit within three years (Kenney & von Burg 1999: 81). Partly thanks to another invention, Hoerni's invention of the planar process in 1960 (with allowed for mass production), and thanks to large contracts from IBM, the US Air Force and NASA, Fairchild soon became bigger than Shockley. In a short time its turnover grew to reach $ 130 million in 1963. Since Fairchild Semiconductor made a profit within three years, the founders-entrepreneurs had lost their claim to shares in 'their' company. This time it was the traitorous eight who felt betrayed.

By 1968, all eight engineers had left Fairchild. Robert Noyce, Gordon Moore and Andy Grove became "world famous" when they founded Intel Corporation (the inventor of the microprocessor). Hoerni, Roberts and Kleiner founded Amelco (which later evolved into Teledyne Semiconductor), Charles Sporck moved to National Semiconductor and Jerry Sanders founded AMD. In the eighties, about half of all the semiconductor companies were direct or indirect descendants of Fairchild. In 1968, Noyce and Moore, together with Andy Grove, began to feel that working within the larger Fairchild setting (the core activity was cameras, semiconductors were merely a secondary activity) began to restrict their opportunities. Furthermore, there was a disagreement between Noyce and Moore on the one hand, and the Fairchild holding on the other, about stock options for engineers. Noyce and Moore saw stock option as a reward instrument for all employees, and not just for management (Rogers & Larsen 1984: 124; Cringely 1996: 39). In addition to serving as an extra reward, stock options were also suitable to attract and maintain highly trained and motivated personnel. The three founders-entrepreneurs of Intel had no trouble at all finding venture capital. The story goes that Arthur Rock managed to acquire $ 5 million by telephone within 30 minutes (Rogers & Larsen 1984). The young company had the wind in its back right away when one of its researchers, Ted Hoff, invented the microprocessor in 1971.

The strong reduction in military contracts in the early seventies was compensated in the semiconductor industry by a growing demand from the computer industry, which especially benefited the new companies like Intel, AMD and National Semiconductor. Unlike their descendants ('the Fairchildren'), the two parent companies did not end up all that well (see figure 4). Shockley's company was sold in 1960 and finally had to close its doors in 1968. Shockley himself worked as a part time professor at Stanford University later on. In 1979, Fairchild was bought by the French company Schlumberger, taken over by the Japanese company Fujitsu nine years later, and was finally 'adopted' by one of its spin-offs (National Semiconductor). In the eighties, the semiconductor manufacturers from Silicon Valley encounter fierce competition from Japanese companies as well as a competing cluster at home, namely the Austin-San Antonio Corridor in Texas. The Japanese competition forced Intel, AMD and National Semiconductor to innovate: they needed to come up with computer chips that were even faster, better and cheaper. As a result of competition from the Far East, a number of collaborations emerged between the American semiconductor manufacturers, aimed at sharing te research costs and the development of new micro-electronics applications, such as the ASIC and RISC chips. These collaborations (i.e. Micro-electronics & Computer technology Corporation (MCC) and the Sematech consortium) between micro-electronic companies from Silicon Valley, Texas and Route 128 and the setting up of new branch offices in the South-East of the US, gradually caused the Bay Area to lose its exclusive right to manufacture semiconductors and computer chips.

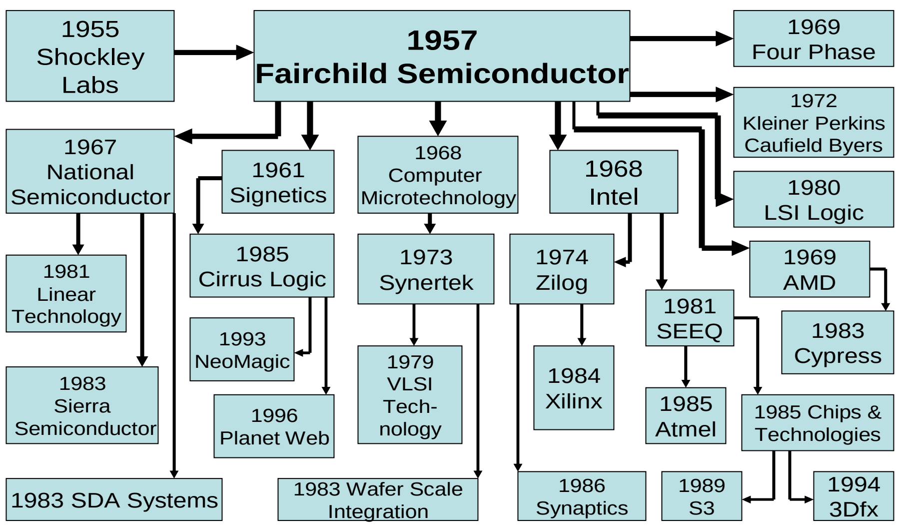

Figure 5: the Fairchild family

However, Stanford University, together with local computer chip and microprocessor companies, had already developed another initiative by founding a new R&D centre in the field of Very Large Scale Integrated (VLSI) computer chips, the Center for Integrated Systems (CIS), founded in 1981. Initially, CIS/VLSI was funded by 18 industrial sponsors, who together provided $ 40.5 million, to which the Department of Defense added another $ 8 million for additional research contracts. Stanford University committed to the project by taking on the management of CIS and by training highly qualified electro-technical engineers (100 Master students and 30 PhD's), who would be the first available staff for the sponsors.

At that time, flexible production networks had developed in Silicon Valley between the established companies, like National Semiconductor and AMD, who focused on the mass production of chips, and newcomers who specialised in custom-made products or parts of computer chip manufacturing. This meant that, in parallel with the growth of the semiconductor industry, there were suppliers of capital goods and materials needed to design and manufacture semiconductors. This infrastructure simplified and stimulated the emergence of specialised start-ups. In the same period the financing of start-ups by venture capitalists increased. Many successful entrepreneurs decided to reinvest their profits in start-ups and to give them advice, not least to minimise the risks. Castells and Hall (1994: 19) point out that venture capital, which was abundantly available in Silicon Valley, there are more than 200 venture capital companies active in Silicon Valley (Aoki & Takizawa, 2002) from the 1970s onwards, did not come from the financial sector but from the industry itself. The availability of venture capital depended not only on the performance of the individual companies and the local industry as a whole, but also to a large extent on the government's fiscal policy (Rogers & Larsen 1984). In 1969, there was $ 171 million in venture capital, which dropped to $ 39 million in 1977 (capital gains tax had increased from 29% to 49%), after which it rose to $ 570 million (capital gains tax reduced to 28%), and reached a ceiling of $ 1.3 billion in 1981 (tax further reduced to 20%). It is precisely in that period that now well-known venture capitalists like Kleiner, Perkins, Caufield & Byers (who invested in SUN, Netscape, America Online, Amazon.com, Excite, and Google), Sequioa (Oracle, Cisco, Yahoo! and also Google) and Mayfield (3Com, Silicon Graphics and Genentech) and the law firms specialising in high-tech entrepreneurship like Sonsini and Fenwick reached maturity.

The third generation of companies: from PC's and databases to the Internet

The dominant industrial system in Silicon Valley is network-based. Instead of the traditional integrated management whereby the entire production process is carried out in-house, a structure has developed of mutually dependent, highly specialised companies. The open, informal and pioneering culture contributed a great deal to this. There is a lot of freedom to experiment, and risk-taking is considered a virtue rather than a sin, and the associated risk of failure is accepted. The emergence of Silicon Valley occurred at the same time as the civilian breakthrough of the semiconductor industry. The industry's pioneers were young and technology-oriented, had a common background (Stanford or MIT) and many of them had worked at Fairchild (the Fairchildren) and had received a famous training ("Fairchild University"). The collective identity has stimulated network formation and informal communication. Often, these ties appeared stronger than belonging to a certain company; as Saxenian (1994: 30) puts it: *"They created firms that were organized as loosely linked confederations of engineering teams"*. Due to the many opportunities in the region, people move about quite a bit. Although people are asked to sign non-disclosure contracts, a great deal of knowledge and skills are exported implicitly, which provided a strong stimulus to the diffusion of knowledge in the region. Some people knew each other from Stanford and, or Xerox Palo Alto Research Center, both talent nurseries. Examples of this are the founders of companies like Apple, SUN, Cisco, Silicon Graphics, Netscape, Excite, Yahoo! and Google.

Apple was founded by Steve Jobs and Steve Wozniak, two university drop-outs and ardent computer hobbyists. Like so many in their generation, they were active in the Homebrew Computer Club, founded in 1975 by a close-knit and fanatical group of enthusiasts in and around Menlo Park. The first meetings took place in the garage of one of the founders, later meetings took place in the Stanford auditorium. Like their illustrious local predecessors Hewlett and Packard, Jobs and Wozniak decided to set up their own company, working from a garage (in this case that of Jobs' parents in Los Gatos). Another source of inspiration was the first commercial supplier of personal computers (or rather minicomputer kits), the Altair of a company called MITS from Albuquerque (New Mexico). Jobs and Wozniak both had working and programming experience: Jobs worked at computer game pioneer Atari (founded by Nolan Bushnell), and Wozniak at Hewlett-Packard. The concrete idea for a modern computer that would be more than a collection of print cards (like the first computer, the Altair from 1975) arose when Jobs and Wozniak want to sell their first design for the Apple I (in the form of a computer kit) in the first specialised computer store in the world: The Byte Shop in Mountain View (Rogers & Larsen 1984: 10).

After their respective employers turned down their idea (but did not object to them developing it themselves) Jobs and Wozniak decided to develop their first computer, the Apple II, using 'some' electronics components from Atari and HP. In 1976, they founded the Apple computer company, together with Intel veteran Mike Markkula. Markkula, Intel's former senior marketing manager, helped the inexperienced entrepreneurs write a business plan and acquire financial resources ($ 91,000 of their own money for a third of the company, a $ 250,000 credit from the Bank of America and $ 600,000 from venture capitalists). Furthermore, Markkula suggested bringing Mike Scott, an experienced National Semiconductor manager, on board as president of Apple. At the end of the seventies, Jobs and Wozniak were to adopt and perfect the mouse interface, icon and pull down menus they 'happened' to see at a tour of Xerox's PARC lab. In 1979, Jobs was given a tour by Larry Tesler (a member of the Homebrew Computer Club), with all the consequences for the development of the PC. As far as Jobs was concerned, a visit to PARC, like the Xerox Alto computer, was 'information at one's fingertips'. Later, Tesler was also hired by Apple to further develop the new graphical interfaces. From the start, Apple was an innovative, creative and somewhat chaotic company, which in addition was 'lean', in the sense that specialised companies were used to manufacture parts and components.

Jobs and Wozniak decided to leave the garage for the new generation of computers, the Apple II, and to move to a building in Cupertino. After that, things went fast, within four years the company was listed at the stock exchange, and founders Jobs and Wozniak, and with them Scott, became multimillionaires overnight (the fourth man Markkula already was). Next to the 40% of the company that was owned by the founders-entrepreneurs, 60% was in the hands of venture capitalists: they had no reason to complain either, with a return of $ 243 for every dollar they had invested (Rogers & Larsen 1984: 18).Over the years Apple generated few spin-offs: the best-know are Radius, Be Labs, General Magic and Claris. On the other hand, Apple employees, especially when the company went through a rough period in the early 1990s, did switch to other companies, among which Netscape was the favourite. Apple succeeded to recreate itself by introducing iPod, and the iTunes store. Apple's renewed success became evident in its increasing stock market value during the period 2003-2005.

A company that flourished in Apple’s wake was Adobe. This company was founded in 1982 by John Warnock, who developed algorithms for three-dimensional representations at the University of Utah, and who, together with fellow founder Charles Geschke had continued to work on the subject at Xerox PARC. Although Xerox was not interested in the technology, it was the basis for later products in the area of desktop publishing, design and graphics industry software, and of the PostScript language, which made it possible to print PDF files. Although relatively unknown, Adobe, after several strategic acquisitions, is one of the largest computer companies in the United States. For a long time, its strong link with the Apple hardware was its biggest problem. Thanks to alliances with Microsoft and Sun, this lock-in relationship was broken.

Another company that was founded in 1982 is Silicon Graphics Inc (SGI), by Stanford professor (computer sciences) Jim Clark and Marc Hannah, a student. The reason for setting up the company was a sponsored research project for the design of a computer chip with a gigantic capacity that would be suitable for animation applications (the ‘geometry engine’). Silicon Graphics has become an important player in the area of ‘mips’ (= millions of instructions per second) microprocessors (due in part through the acquisition of MIPS Technologies Systems), super-computing (especially after it took over Cray) and specialises in animation and 3D technology. The company focused on visualisation technologies, and as such it had close links with Hollywood (for instance, SGI made an important contribution to films like Forrest Gump and Jurassic Park). SGI encountered increasing competition from HP and Compaq Computers. SGI became a company in search of a new strategy, and in 2006 filed for Chapter 11 bankruptcy protection, as part of a plan to reduce its debt. In October 2006 it was announced that SGI has emerged from Chapter 11 protection.

Oracle was founded around the same time as Apple and Silicon Graphics, and at the turn of the century is one of the biggest database companies. Its founder Lawrence Ellison combined the concept of relational databases with SQL, which were both developed by IBM, and thus made it possible to extract any kind of date from company databases. In 1979, Oracle developed the first SQL-based Relational Database Management System (RDBMS), which meant that it managed to market this product before IBM did. Oracle's database technology is so fundamental and sturdy that the company's position is very strong. Oracle is developing into a full service software and consultancy company. In 2004 Oracle acquired its competitor Peoplesoft in a hostile take-over.

An important player, especially with regard to impulses towards the Internet, is SUN. SUN originally is an acronym for Stanford University Network, which is an indication as to where its roots lie. SUN is a powerful workstation that was developed in 1981 by Andreas Bechtolsheim, who was frustrated that he had to go the computer centre every time he needed a powerful system. His previous experience at Xerox PARC, where he saw the concept of simple desktop computers connected to a network, and his knowledge of computer technology, allowed him to build his first computer on the basis of standard components. SUN is an open system that uses UNIX. Sales went so well that Khosla (a Stanford MBA graduate who had started his own company before, and also later in his career became partner of Kleiner, Perkins, Caufield & Byers), in 1982 convinced Bechtolsheim to start a company together. Scott McNeally, a Harvard economist (and Stanford MBA) and Bill Joy, a UNIX expert from the University of Berkeley, were also involved in the creation of SUN Microsystems. The UNIX operating system has always been an important business driver for SUN, as becomes clear by alliances with, among others, AT&T for the development of the business standard for UNIX and for the development of UNIX servers. Further alliances with Oracle and other database suppliers like Informix and Sybase have allowed to expand its position as market leader further.

In addition to SUN, Cisco played a major role in the breakthrough of Internet technology. Like SUN, Cisco originated at Stanford and like SUN it was set up in the early eighties. Leonard Bosack and Sandy Lerner, a married couple working as network managers for different faculties, were looking for a solution, other than the connection via mainframes, that would make it possible, to connect networks. Together with students they developed the router, a device that made it possible to connect network at a fraction of the then current costs. In 1984, they started Cisco Systems Inc. from their home. It has been said that the start-up mentality has been crucial to Cisco's success (Cohan 1999: 30). Cisco is highly customer-oriented, places great value on cooperating with its customers (*don't just become a Cisco client, become a Cisco partner*), and leads the way when it comes to e-commerce applications and the support of all kinds of customer self-services processes with Internet technology. Cisco works hard on maintaining its technological lead. On the one hand, it does so through acquisitions aimed at gathering core competences, and on the other hand by attracting competent employees. An example of such a takeover is Granite Systems, just another company that was founded by Bechtolsheim. Bechtolsheim was involved earlier in setting up SUN, and after he had left SUN with $ 50 million in shares had started a new company to develop a fast computer chip with which Gigabit Ethernet could be run. Cisco controls the market for Internet network hardware, with a market share of 85%. Cisco's strategy, under John Chambers (former Wang director) is to become the third major high-tech monopolist next to Intel and Microsoft, although that means the company has to deal with parties operating in the traditional network sector, like Lucent and Nortel.

The companies that have been discussed thus far, like Hewlett Packard, Apple, Silicon Graphics, SUN and Cisco, are among the companies that have produced enabling technologies for the Internet, i.e. relevant hardware and software, and are continuing to do so. However, these were the companies that really felt the downturn after the deflating of the Internet bubble, but succeeded to survive. The dramatic decline of market capitalization, substantial losses and declining revenues led to exit of executives, layoffs, and expense-reduction efforts. Sun started to make profits again in 2005. Silicon Graphics almost went bankrupt, Apple survived only due to the iPod. A large number of the next generation companies in Silicon Valley however did not survive when the Internet bubble burst.

The fourth generation of companies: the Internet intermediaries

The next generation of companies focuses more on easy access to the Internet, searching the web and on push-media. A pioneering company in the web browsing market is Netscape, co-founded by Stanford professor and founder of SGI Jim Clark. Excite and Yahoo! focused on searching the web. Excite was founded in 1994 by Stanford students Graham Spencer and Joe Kraus, Mark Van Haren, Ryan McIntyre, Ben Lutch and Martin Reinfried, with financial support from Kleiner & Perkins partner Khosla. Yahoo! was founded in 1995 by Jerry Yang and David Flo, also Stanford PhD students. Yahoo! eventually moved from a search engine to a portal. Although many of these companies provided a strong impulse to the development of the Internet, they hardly have a lasting competitive edge as became apparent during the dotcom crisis. This can be explained to some extent by the low entry barriers for companies wanting to set up similar activities, the fact that in the information economy many ideas are easily copied, and the relatively short time they had to try and establish a market leadership (Shapiro & Varian 1999; Cohan 1999). For instance, due to fierce competition from Microsoft and IBM, Netscape's business model did not prove strong either, and in 1998 the company had to accept a $ 4.2 billion offer from America Online (AOL), and Excite, in 1999 taken over by At Home for $ 6.7 billion, went bankrupt in 2001. The dominant development model for Internet companies that arose in the early nineties seems to lead from Internet intermediaries like search engines and portals to content providers and media companies. This trend is most probably the exponent of the convergence of the Internet and the East Coast based content industry.

Google is the most illustrative example of an Internet intermediary moving in the direction of offering content. As with many other companies in Silicon Valley the two founders of Google Larry Page and Sergey Brin are two former PhDs in the computer sciences at Stanford University who decided to give priority to their venturing activities. They started Google traditionally in a garage in Menlo Park, with initial financial support from Andy Bechtolsheim, and later from both Kleiner & Perkins and Sequoia. Google entered the Internet domain rather late in 1999. Google offers a search service based on advanced algorithms, able to analyze *back links* from web pages, and distributed computing. In 2001 Google already made profit, with almost no marketing effort, but a well-planned PR-campaign towards the media. Google's IPO was in 2004. Google initially made money by selling their search technology to customers, who can use it on their own sites, and by a keyword advertising programme. In 2002 Google introduced a cost-per-click pricing model. Google generated 98% of its sales from text ads, placed around search results. After their IPO, Google introduced a wide range of new services, expanding their original strength the Internet search; among the new products and services are Gmail, Google Desktop, Google Maps, Google Book Search, Google Talk, Froogle (online shopping engine), and Google Earth. The recent acquisition of the start-up firm YouTube by Google has not only allowed for an integration of YouTube's and Google's video sharing facilities, but when combined with its s search engine and electronic marketing capabilities, Google was able to capture a new wave of customers and users groups from all over the world in this newly emerging 'personal video' market.

In 2005 Google took a minority share of 5% in Time Warner's AOL. Google's success did lead to the question if Google was not becoming too powerful to stay a partner of AOL. As a consequence of Google's strategic partnerships deals with Dell and Sun and through the offerings of its distinctive stand-alone applications and desktop extensions (e.g. Gmail, Picasa, Pack, Talk, Toolbar, Blogger Web), Google is effectively penetrating the software market and is becoming a serious threat to Microsoft. Google is also entering the mobile (software) market, developing a software platform for mobiles, and experimenting with online payments, i.e. Google Wallet, basically by teaming up with wireless and mobile start-ups. eBay, owner of the competing PayPal payment platform, and Amazon are concerned with Google's huge user base, and their push into eCommerce. The question remains open how Google is going to affect the media, and technology business landscape. But it will be evident that Silicon Valley will be its playing ground. Silicon Valley will be more integrated with the content industry. Not only the convergence of Internet with the media industry will be discussed in the near future of Silicon Valley, also the expected convergence of biotechnology with information and nanotechnology will be shaping Silicon Valley's future.

DISCUSSION AND CONCLUSION

An important element in the development of high-tech regions has to do with knowledge transfer in its various forms. This does not just refer to the role of knowledge infrastructure and the various ways in which knowledge is distributed (through talent acquisition and recruitment, and licensing as with MIT and Stanford), via the role of science and technology parks en incubation centres, but also to the role of central knowledge enterprises that transfer and use developments. In this respect it is striking that especially in Silicon Valley, there is a much higher degree of openness and willingness to exchange information and share knowledge with the network of relevant contacts, suppliers and customers. Although various knowledge transfer mechanisms are in place in Route 128 as well, generally speaking there is a tendency to keep information and knowledge much more within the own organisation. In addition, labour mobility in Route 128 is much lower than it is in Silicon Valley. Undoubtedly the organisational structure of large dominant enterprises, the vertically integrated (mini)computer manufacturers like DEC, Data General and Prime, as well as the need for secrecy associated with some defence contracts, has played a role in that respect. Against the vertically integrated production system of Route 128, Silicon Valley has its horizontal networks consisting of a number of core companies with a flat organisational structure and relatively small-scale suppliers. Furthermore dynamics are high, with a high labour mobility and a large number of spin-offs and start-ups.

Also, the role of technology customer is important. In Route 128 it is especially the military industrial complex, and with it the Federal Government (Pentagon, NASA, DARPA) that has played a major role. The spin-offs using military technology for civilian purposes have not been insignificant (e.g. Raytheon, DEC, Data General). The same is true in the case of Silicon Valley. However, in the case of Silicon Valley civilian applications started playing an increasingly important role from the 1970s onward, and have developed into a driving force of their own. Especially the semiconductor, PC technology, and the network technologies that have led to the new wave of Internet-related innovation, are rooted in Silicon Valley. The increasing acceptance and economic use of Internet technologies has also led to a different kind of customers and the emergence of clusters close to the customer, for instance the media and entertainment industry. Silicon Valley illustrates the shift towards the advertising and media sector and the possible convergence of content, hardware and software..

Capital has become and increasingly important lubricant. Together with the shift from a focus on military technologies and products towards civilian applications, funding has shifted from the (Federal) Government towards the private sector, especially venture capital with banks playing a limited role. With the success of the region, the role and size of venture capital increases. Successful entrepreneurs are prepared to reinvest the capital they have earned in new technologies and business concepts, and make as such a substantial contribution to *serial entrepreneurship* and *informal investing*. Venture capitalists hitch a ride on the success of successful enterprises and their capitalisation via an IPO. Because they benefit financially from the success of the companies in which they have invested, the capital at their disposal increases further, allowing them to reinvest it again, causing a kind of flywheel effect. Especially in Silicon Valley this has led to a unique kind of dynamics. In the 1960s, Noyce and the other *traitors* of Shockley's Semiconductor were forced to look for funds on the East Coast before being able to set up Fairchild Semiconductor on the West Coast. After they made their company into a success and realised the industry's potential, they decided to leave Fairchild and set up their own company. These *traitorous eight* (and the companies they have started) are now among the most important local investors in the region as business angels (e.g. Gordon Moore), as venture capitalists (Eugene Kleiner) or through a business investment fund (Intel's corporate venture fund).

Except investors, venture capitalists are also network brokers, they provide the missing links in the management of new companies. By establishing new contacts with customers, distributors and new management they provide new and vulnerable companies with a broader techno-economic foundation and a higher degree of social legitimacy. Together, the wheeling and dealing of venture capitalists, the continuous creation of spin-offs and the high level of workforce mobility create a *rich* network. Rich in a financial sense but also with regard to the variety of contacts and sources of information. In addition, ICT clusters have developed networks, platform, and communities for collective knowledge creation, information sharing and interest representation. In short, an effective high-tech cluster requires more than just money and business experience, it also requires knowledge and – perhaps more importantly – networks. Apart from the driving forces, such as the presence of talent and wealthy customers, the role of venture capital, and the availability of knowledge and contacts, a specific culture and innovative entrepreneurship (the possibility to fail, the development of creativity, the utilisation of opportunities and coincidences), and the quest for (financial) success play an important role in all areas. That it is Silicon Valley that has as yet the greatest potential is obvious. This confirmation of *success breeds its own success* can be found in the fact that the region keeps reinventing itself and in the effective transition towards working on and with new groundbreaking technologies.

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