THE EVOLUTION OF RESEARCH AND DEVELOPMENT IN US INDUSTRY: FROM CORPORATE R&D LABORATORY TO VENTURE CAPITAL FINANCED STARTUPS

MARTIN KENNEY AND RICHARD FLORIDA

Reprinted from
HITOTSUBASHI JOURNAL OF COMMERCE & MANAGEMENT
Vol. 24 No. 1 (Whole Number 24) December 1989

The Hitotsubashi Academy
Hitotsubashi University
Kunitachi, Tokyo
Japan

Hitotsubashi Journal of Commerce and Management 24 (1989) pp. 41–51. © The Hitotsubashi Academy

THE EVOLUTION OF RESEARCH AND DEVELOPMENT IN US INDUSTRY: FROM CORPORATE R&D LABORATORY TO VENTURE CAPITAL CAPITAL FINANCED STARTUPS*

MARTIN KENNEY AND RICHARD FLORIDA

I. *Introduction*

It is remarkable that forty years after Schumpeter and Galbraith prophesied the end of entrepreneurial innovation in the US economy small companies are still at the forefront of many of the highest technologies such as semiconductors, computers, biotechnology and, more recently parallel processing, artificial intelligence and superconductivity.[1] Even as high technology industries seem to become more predictable and stable, new innovations repeatedly destabilize the situation allowing new startups to form and creating the space for new firms to occupy.

In the postwar period within large US companies, innovation and manufacturing were separated in such a way as to enourage entrepreneurs to start their own companies to actualize their innovations. The tremendous success of the early entrepreneurial companies eventually evolved into what the author's term "innovation complexes" such California's Silicon Valley and Boston's Route 128. As these complexes developed they became self-reinforcing and an entire infrastructure was built up to assist the small startup in organizing itself and growing rapidly. It is in the context of these complexes that the breakthrough innovations are created by what are essentially "self-organizing" teams. In fact, these innovation complexes can be conceptualized as "virtual" corporations, that is, as resembling a single company, in which information and personnel flow incessantly combining and recombining in the development of new companies.

This paper traces the history of the breakdown of innovation in the large US company and the rise of Silicon Valley and Route 128. We also discuss the organization of research

* This paper is based in part on themes presented in the authors' forthcoming book, *The Breakthrough Economy: The Separation of Innovation and Production in High Technology Industry* (NY: Basic Books, 1989). Much of our discussion is drawn from interviews we have conducted with entrepreneurs, venture capitalists and industrial researchers in U.S. high technology companies and executives and industrial researchers in Japanese corporations; we gratefully acknowledge their assistance. We would especially like to thank Harvey Brooks, Gordon Clark, Marshall Feldman, Thomas Murrin, Ron Rohrer and Seiichiro Yonekura for their helpful insights.

[1] In keeping with the definition proposed by Joseph Schumpeter, we define innovation as "a product or process that is, in a technological sense, new and has met the market test." For this exact wording see, Nancy Dorfman, *Innovation and Market Structure* (Cambridge, MA: Ballinger, 1987).

and development in the small entrepreneurial companies and compare it with the more bureaucratic organization of large companies. We then turn to the crucial importance of venture capital in assisting small company startup. In the concluding section we reflect upon the weaknesses of small startup firm method of commercializing high technology.

II. *An Assembly-line Model of Innovation*

In the early twentieth century the U.S. developed a new form of mass production industrial organization based upon the assembly-line. Giant industrial factories combined taylorist ideas of scientific management with the mechanized flow of the assembly-line.[2] Simultaneously, these large corporations created corporate research laboratories aimed at internalizing technological change and capturing the innovative dynamism previously associated with independent entrepreneurs. With GE's Research Laboratory and Bell Labs as models, hundreds of industrial corporations founded research laboratories during the first few decades of the twentieth century.[3] During this early period research labs were located near factories and there was a constant interaction and communication between manufacturing and R&D. When new products were developed they could easily be transferred to production.

World War Two was a watershed for industrial research. During the war US scientists and engineers had developed new technologies and new weapons which made a clear contribution to the war effort. After the war the federal government became massively involved in the promotion of science and technology through increased Defense Department spending and the newly established National Science Foundation and National Institutes of Health. Companies dramatically increased their own outlays on research as well. Total spending on R&D (using 1982 constant dollars as a benchmark) grew from roughly $20 billion in the early 1950s to more than $100 billion by 1987. However, much of the federal dollars were spent upon weapons research and a similar emphasis on military research gripped US industry.[4]

In the postwar period US managers began to conceptualize innovation as an assembly-line beginning with basic research and ending with manufacturing. The various elements of the innovation process—basic research, advanced development and manufacturing—were separated from one another. Further, within the research laboratories personnel were divided up on the basis of academic discipline, thus mechanical engineers were grouped

---

[2] For a discussion of this development see, David Hounshell, *From the American System to Mass Production* (Baltimore: Johns Hopkins, 1984).

[3] Recent years a number of books have been published describing the historical evolution of industrial research. Especially useful are the following: David Noble. *America By Design: Science, Technology and the Rise of Corporate Capitalism* (New York: Oxford, 1977); David Hounshell (ed.) *The R&D Pioneers* (forthcoming). For a comprehensive overview of recent research is provided in Michael Dennis, "Accounting for Research: New Histories of Corporate Laboratories and the Social History of American Science," *Social Studies of Science* 17, (1987) pp. 479–518.

[4] Military research is very attractive because it is often done on costplus contracts guaranteeing a return irregardless of whether the research is successful. For further discussion regarding military R&D see, Nathan Rosenberg, "Civilian 'Spillovers' from Military R&D Spending," in Sanford Lakoff and Randy Willoughby (eds.) *Strategic Defense and the Western Alliance* (Lexington, MA: Lexington, 1987) pp. 165–88. Also, see Seymour Melman, *The Permanent War Economy* (New York: Simon and Schuster, 1974).

and development in the small entrepreneurial companies and compare it with the more bureaucratic organization of large companies. We then turn to the crucial importance of venture capital in assisting small company startup. In the concluding section we reflect upon the weaknesses of small startup firm method of commercializing high technology.

II. *An Assembly-line Model of Innovation*

In the early twentieth century the U.S. developed a new form of mass production industrial organization based upon the assembly-line. Giant industrial factories combined taylorist ideas of scientific management with the mechanized flow of the assembly-line.[2] Simultaneously, these large corporations created corporate research laboratories aimed at internalizing technological change and capturing the innovative dynamism previously associated with independent entrepreneurs. With GE's Research Laboratory and Bell Labs as models, hundreds of industrial corporations founded research laboratories during the first few decades of the twentieth century.[3] During this early period research labs were located near factories and there was a constant interaction and communication between manufacturing and R&D. When new products were developed they could easily be transferred to production.

World War Two was a watershed for industrial research. During the war US scientists and engineers had developed new technologies and new weapons which made a clear contribution to the war effort. After the war the federal government became massively involved in the promotion of science and technology through increased Defense Department spending and the newly established National Science Foundation and National Institutes of Health. Companies dramatically increased their own outlays on research as well. Total spending on R&D (using 1982 constant dollars as a benchmark) grew from roughly $20 billion in the early 1950s to more than $100 billion by 1987. However, much of the federal dollars were spent upon weapons research and a similar emphasis on military research gripped US industry.[4]

In the postwar period US managers began to conceptualize innovation as an assembly-line beginning with basic research and ending with manufacturing. The various elements of the innovation process—basic research, advanced development and manufacturing—were separated from one another. Further, within the research laboratories personnel were divided up on the basis of academic discipline, thus mechanical engineers were grouped

[2] For a discussion of this development see, David Hounshell, *From the American System to Mass Production* (Baltimore: Johns Hopkins, 1984).

[3] Recent years a number of books have been published describing the historical evolution of industrial research. Especially useful are the following: David Noble. *America By Design: Science, Technology and the Rise of Corporate Capitalism* (New York: Oxford, 1977); David Hounshell (ed.) *The R&D Pioneers* (forthcoming). For a comprehensive overview of recent research is provided in Michael Dennis, "Accounting for Research: New Histories of Corporate Laboratories and the Social History of American Science," *Social Studies of Science* 17, (1987) pp. 479–518.

[4] Military research is very attractive because it is often done on costplus contracts guaranteeing a return irregardless of whether the research is successful. For further discussion regarding military R&D see, Nathan Rosenberg, "Civilian 'Spillovers' from Military R&D Spending," in Sanford Lakoff and Randy Willoughby (eds.) *Strategic Defense and the Western Alliance* (Lexington, MA: Lexington, 1987) pp. 165–88. Also, see Seymour Melman, *The Permanent War Economy* (New York: Simon and Schuster, 1974).

into a department, as were electrical engineers etc. Communication between elements of the innovation process and between disciplinary departments was required to be through channels. A project was essentially sent down the innovation assemblyline. When one group finished its work on the project if was "thrown over the partition" to the next group with little or no communication. The result was poor communication and the design and development of products that were manufacturable. To enforce this new system a new breed of professional research managers was created and brought all of the techniques of "modern management" to the research laboratories including ROI calculations, tight job descriptions, hierarchical channels of communication and increasing layers of new managers.[5]

The decentralization of manufacturing facilities during the 1960s and 1970s led to greater estrangement. Older plants in the industrial heartland were replaced with new ones in growing regions like the sunbelt and in third world countries. With the manufacturing plants gone, research functions were relocated to suburban campus settings. Initially, it was thought that separating research laboratories from manufacturing would provide the insulated environment needed to achieve important breakthroughs. But, this only increased the physical and social distance between research and manufacturing and innovation suffered. For example, among the manufacturing divisions at RCA the research laboratories became known as the "Country Club," As the two groups became increasingly estranged, manufacturing refused to have anything to do with the research laboratories and the research laboratories came to feel entirely superior to the less academic manufacturing divisions.[6]

All of this combined with an increasing bureaucratization of the firm so that researchers would propose projects and they would wait years for a response as to whether they could go ahead. Research projects would be started on a crash basis, then would be put on hold, and eventually cancelled. Or conversely, research projects would begin, be cancelled, then revived and put on hold. Researchers could work several years on a project and then find out suddenly that it was terminated. They felt helpless and had little say in management decisions. For these creative people the knowledge that their projects were at the mercy of bureaucrats was extremely frustrating and they began to look for alternatives.

By the 1950s, the assembly line model had created obstacles to innovation. Management had grown complacent as one good year followed another. Researchers often faced sizeable barriers getting companies to move forward with their ideas. Even when new technologies were developed, with manufacturing far removed from research centers, large corporations were unable to mesh new technologies to existing manufacturing capabilities or to their longer-run strategic objectives. There was seemingly little alternative. Gradually, researchers and other personnel began to seek out and to create new institutional arrangements for realizing innovations.

---

[5] For a more general critique of this type of professional management see, Robert Hayes and William Abernathy, "Managing Our Way to Economic Decline," *Harvard Business Review (July–August 1980) : 67–77.*

[6] For a powerful discussion of the RCA experience see Margaret Graham, *RCA and the Video Disc: The Business of Research*, (New York: Cambridge, 1986).

III. *The Reemergence of Entrepreneurial Innovation*

The styming of the commercialization of technological developments in the large corporations provided the space in which new companies could grow. Though the genesis of these new industries was inside large companies and universities, increasingly small companies became the vehicle for catalyzing the new breakthrough innovations. In the early 1950s the computer was developed and the initial commercialization occurred through startups like Eckert and Mauchly's University of Pennsylvania spinoff and Engineering Research Associates. However, these were quickly absorbed by companies like Sperry-Rand. However, Sperry-Rand moved slowly in exploiting its advantages and was rapidly passed by IBM.

In 1957 three important new companies—Fairchild Semiconductor, Digital Equipment Corporation (DEC), and Control Data—were founded and these would herald the reemergence of entrepreneurial innovation. Fairchild and DEC became the bases upon which Silicon Valley and Route 128 would be built. Fairchild would over the next thirty years spffino companies both in semiconductor production and semiconductor equipment production. Fairchild (or Fairchildren and, eventually, Fairgrandchildren as they came to be called) were involved in almost every important startup in the Valley. Similarly, employees left DEC to start Data General, Prime Computer and numerous other companies. Not only did Fairchild and DEC provide employees to their respective areas, but they also helped in the early development of venture capital.[7]

The secret to the success of these high technology startups were that they developed a research environment completely different from that of the large traditional companies. R&D was typically organized in ad hoc and informal teams. Scientists and engineers and often marketing people worked in highly interactive small teams under intense pressure to develop products for the marketplace. In the company's infant stage there is no bureaucracy reject projects or to hinder the team as it strains to meet deadlines. Young engineers are given difficult tasks and are under intense pressure to finish them rapidly. Often this leads to new breakthroughs.

The motivation for top engineers to leave traditional companies was two-fold: First, to try to develop a new breakthrough, that is, to create a new product that actualizes their vision. Second, there was the potential to become very rich if the company is successful. For example, when Apple Computer stock went public over one hundred employees became millionaires. An important recruitment tool for top engineers and other key employees are stock options and other ownership stakes which tie them closely to the success of the business. This organizational synthesis enabled small high technology companies to attract extremely motivated researchers and become the focal point of important breakthroughs.

Increasingly, startups became the places where "high energy" researchers could make

[7] For further discussion of this see the following sources: Everett Rohers and Judith Larsen, *Silicon Valley Fever*, (New York: Basic, 1984); John Wilson, *The New Venturers*, (Wellesley, MA: Addison-Wesley, 1985); Richard Florida and Martin Kenney, *The Breakthrough Economy*, (New York: Basic, forthcoming).

their new ideas happen. So, for example, 11 of 18 major semiconductor innovations made during the 1970s came from small startups. The more recent custom chip revolution has occurred almost exclusively through the vehicle of entrepreneurial ventures like LSI Logic, Cypress Semiconductor and a host of others. Entrepreneurial computer firms such as Apple, Cray and Sun pioneered critical breakthroughs in the areas of personal computers, supercomputers, and computer workstations, respectively. The rapid transformation of biotechnology from university science to a nascent industry was premised upon the action of venture capital-backed startups like Genentech, Cetus, Amgen and Integrated Genetics.[8]

The strength of this method of organizing innovation is obvious—in market after market these small companies perfect and introduce the newest technologies. For example, it was Apple Computer and a host of other small companies that created the personal computer business and not IBM, DEC, Hewlett-Packard and Xerox. Again, in biotechnology it was the small companies that opened the entire field to commercialization. More recently, in computer work stations it was not large computer companies such as IBM, DEC, NEC or Fujitsu that pioneered these new fields.[9] Rather, these large companies were unable to recognize these new trends which would rapidly open billion dollar markets and create entire new industrial segments.

IV. *The Role of Venture Capital*

The key feature of professional venture capital is that it provides new ventures with more than just capital. The fact that venture capitalist take an equity position in the startup firm has three very crucial results. The first is that upon taking the equity position they effectively become partners in the firm. The second is that they will make money only if the firm grows and they can liquidate their investment either through a merger or going public. Thirdly, their downside risk is limited (they can lose their investment), while the upside is unlimited.

The use of equity investment rather than debt eliminates the problem of scheduled repayment. It allows young companies to reinvest their earnings and provides an asset base which can be used to attract outside capital and enhance a company's credibility with vendors and financial institutions. Venture capitalists are involved in a wide variety of tasks that are necessary to launch new, high technology businesses.

There are three stages of growth of a firm from entrepreneurial beginnings to the point at which the venture capitalist can sell their equity in the firm. In the first stage venture capitalists evaluate the entrepreneur's business proposal with regard to the following criteria: the originality of the proposed product or technology, its potential competitors, market, size business strategy and projected sales, the availability of patent protection or other proprietary characteristics, the prospects of exiting from the investment, and the quality

[8] For a discussion of venture capital and biotechnology see Martin Kenney, *Biotechnology: The University-Industrial Complex* (New Haven, CT: Yale, 1986).

[9] It is interesting to note that much of the equipment that makes up these new machines was built by Japan nese computer companies and yet they did not pioneer any of these fields.

of the entrepreneurial group.[10]

It is only after carefully screening the business proposal or "business plan" that venture capitalists decide to invest. In this role of selection, venture capitalists act as technological "gatekeepers."[11] The ideal investments are in companies that will be big hits—companies such as Apple, Sun Microsystems, Compaq Computers, or Microsoft taht within five to seven years will have revenues of $100 million, $200 million or $500 million.[12] The returns on the big hits can be as high 100 times the venture capitalist's original investment. This level of success can only come from radical new product innovations. Process improvements or small incremental improvements in products cannot provide the basis for such huge successes and so are not afforded attention by venture capitalists. Similarly, venture capital tends to invest in small companies that have a discrete product to develop. Large systems innovations which require development of an entire series of products to be able to operate are not candidates for venture capital backing.

Once the investment is completed venture capitalists provide significant nonfinancial assistance to the startups.[13] They have substantial experience and contacts which help new companies secure legal counsel, patent attorneys, accounting services, outside technical experts, public relations consultants and a wide variety of ancillary business services as well as locate office or production facilities. However, the most important assistance venture capital gives is assistance in the recruitment of the management necessary to build a large firm.[15] Venture capitalists operate to lower the entry barriers to new firms and to pave the way for rapid business growth.

The role of venture capital changes as the company moves through its growth stages. Over time the relative importance of managerial and marketing skills increase in relation to simple R&D and venture capitalists shifts from more active involvement to one of advice and assistance. In this period the company may be growing at an extremely rapid rate and management is usually so overwhelmed with crises that it can no longer focus on strategy issues. Here again, the intervention of experienced venture capitalists can assist the company in retaining a more strategic perspective. In the final stage of venture capital involvement they can assist the small company in preparing for a public stock offering.

[10] Of all of these criteria our interviews and other research have indicated the quality of the entrepreneurial group is the most important. For a more quantitative assessment see I. Macmillan, R. Siegel and P. Narashima, "Criteria Used by Venture Capitalists to Evaluate New Business Proposals," *Journal of Business Venturing*, 1 no. 1 (1985): 119–28.

[11] Partners in the important venture capital firm, Kleiner, Perkins, Caufield and Byers have taken this gatekeeping function even further. They have identified new technology areas and then had their personnel or former personnel actually launch ground-breaking new companies such as Genentech in biotechnology and Tandem Computer in nonstop computing. In a slightly different but similar case, Brook Byers was instrumental in the founding of Hybritech to exploit monoclonal antibody technology.

[12] This should be qualified with the following caveat. In the end it is, of course, not really important to the venture capitalists what the revenues of teh company are, but rather what investors value the company at when the venture capitalists sell their equity. Thus, in biotechnology none of the major companies had revenues of more than $20 or $30 million when they went public. However, the public found the stocks irresistable and purchased them at such a high price that the venture capitalists were able to get extremely high returns on their investments.

[13] In some cases, fledgling company use unoccupied rooms at the venture capitalist's offices during the new company's formative period.

[14] Thomas Davis (General Partner, Mayfield Fund), Personal Interview (December 1986).

Thus, venture capital adopts the role of both capitalist and catalyst in the process of realizing the economic potential of innovation and new firm formation.

The partnership between the venture capitalist and the startup firm's founder and managers is not based on a total identity of interests. The venture capitalist's primary objective is to secure the greatest possible capital gains. Whereas, entrepreneurs, though motivated by financial gain, are also influenced by a more complex mixture of motivation which includes: profit, the longterm security of having one's own firm, a sense of mission, and an attachment to the firm. Especially as the small firm grows beyond the startup stage, the entrepreneur may no longer have the skills to adequately manage the growing enterprise. At this stage the venture capitalists may use their control of the corporate board of directors or leverage over further rounds of finance to make changes or even remove the founder or the entire entrepreneurial group. This may lead some entrepreneurs to believe that the venture capitalists have "hijacked" their company. Thus, in cases of troubles the venture capitalists can become problematic partners.[15]

Venture capital in economics terms is based on "imperfect markets," and much of success is based on "gut" feelings and quick action. Because of this decisions are based on personal interaction and communication, this means that venture capitalists must be located close to the entrepreneurs. This has meant that venture capital has congregated in the area of the high technology businesses.

V. *Silicon Valley and Route 128*

Silicon Valley and Boston's Route 128 are more than just geographical locations. They have evolved an entire milieu geared to achieving technological entrepreneurship and in the process have become the home to tremendous concentrations of high technology businesses. The venture capitalist, Donald Valentine, has accurately described them as "worlds of intellectual property and not capital equipment or production."[16] One way to think about these innovation complexes is to conceive of them as nuclear reactors within which established companies are constantly throwing off people who then start new companies in a continuous chain reaction with venture capital as the fuel.

What makes an innovation complex is not merely entrepreneurs, but rather an entire infrastructure geared to making small companies grow quickly—and what motivates the entire structure is the tremendous capital gains that can come from an extremely successful company such as Apple, Sun Microsystems, Genentech, DEC or Intel. It is interesting to note that according to the most recent *Electronic Business* magazine that in 1988 Silicon Valley was the home to 42 of the 100 fastest growing U.S. high technology electronic companies, while Boston was the home of 14 more.

Silicon Valley and Route 128 have developed numerous institutions besides venture capital to allow the rapid creation of new companies. There is an infrastructure that can provides legal assistance, copyright and license counseling, marketing assistance, manage-

---

[15] For further discussion see, R. Florida and M. Kenney, "Venture Capital-Financed Innovation and Technological Change in the U.S.," *Research Policy* 17 (1988): 119–37.

[16] Donald Valentine, Personal interview, (April 1988).

ment services, banking, contract manufacturing, subcontracting help, and even advice on how to develop offshore manufacturing facilities.[17] These networks of supports are utilized in the companies early days to help it grow quickly. As in an internal corporate development project which, as it grows requires the resources of different parts of the corporations, so to does a small startup company. In this sense, the innovation complex is a "virtual" corporation providing these services.

VI. *A Breakthrough Evonomy*

The benefits of the entrepreneurial startup company as a model of commercializing innovation have been discussed widely in the literature.[18] Entrepreneurial small firms have made the U.S. very good at breakthroughs innovations; yet these companies often lack the capacity to follow through and capture the full economic rewards of their innovations. Thus, there are some substantial costs to this method of innovation, both at the micro, or corporate-level and the macro- or societal level. We will explore these costs in this section.

These small startups are created by spinoffs from established firms. This means that research teams are constantly being split up by spinouts. The average turnover of engineers in Silicon Valley is 23 percent per annum, however in many companies this can range up to 50 percent per annum.[19] If the average project is two years in duration, this can mean that most engineers have changed companies during the life of the project.[20] Thus, what you have in the US innovation complexes is the self-organization of teams in the form of new companies, but in a hyperfluid environment. Philip Kaufman, then president of the ASIC design company, Silicon Compilers, and now president of a new startup, Clustrix, described the situation in this way:

> One of my guys comes to me with a new idea and I can't finance it beyond a two year time horizon. But, he can go down the street and get three to five million in venture capital to launch his company . . . the problem is how can we figure out a way not to have every new idea develop into a new company.[21]

The retention of skilled employees and corporate information is an important management problem.

[17] Regis McKenna, "Testimony" U.S. Congress, Joint Economic Committee, *Climate for Entrepreneurship and Innovation in the United States* Hearings, (August 27–28, 1984) pp. 31–34.

[18] The classic source here is David Birch, The Job Generation Process, *(Cambridge, MA: MIT Program on Neighborhood Change, 1979). There is a strain of this argument running through the works of Michael Piore and Charles Sabel.* The Second Industrial Divide, (New York: Basic, 1984). Also, a number of geographers have picked up this theme. See, especially, Michael Srorper and Allen Scott, "The Geographical Foundations and Social Regulation of Flexible Production Complexes," in Jenneifer Wolch and Michael Dear (eds.), *Territory and Social Reproduction*, (Boston: Allen and Unwin, 1988).

[19] Everett Rogers and Judith Larsen, *Silicon Valley Fever* (New York: Basic, 1984).

[20] We are indebted to Arthur Rock, the initial venture capitalist to back Intel, for pointitg this out to us in an interview (April 1988).

[21] Philip Kaufman, "Personal Interview," (April 1988).

The problem of employee turnover is exacerbated by what some have termed "venture capitalism."[22] In this situation venture capitalists will target a corporate research team and deliberately entice it to leave and form a new company. For a company to resist such targetting is often difficult because the venture capitalist can offer the research team stock in the company and high salaries. Whereas, the established company must consider the effect that giving comparable salaries to the target employees will have on the overall corporate salary structure. In companies such as Fairchild which was both unwilling and unable to compete, the result was a constant loss of employees which bled the company dry.

Venture capitalists are always searching for new fields to invest in. Often when a new and potentially exciting field for investment has been developed each venture capital fund wants to place bets in that area. This leads to a proliferation of new startups. For example, in the early 1980s in the disk drive industry there were dozens of startups as every venture capitalist wanted to fund a company in this hot new growth industry. This overfunding resulted not only in formation of too many companies, but also in the weakening of the stronger companies as their employees left to form startups at the behest of venture capitalists. By the mid-1980s there was a shakeout and the weakened survivors found it difficult to continue to compete in the world marketplace.[23]

In this environment of job-hopping long-term investment in employees becomes difficult because the company will probably be unable to recoup its investment. This creates an environment in which corporate management is encouraged to extract as much as possible from its highly skilled employees and invest little. This leads to a phenomenon called "burnout," which occurs in engineers that have been working in the pressure cooker environment of a small company startup until the point at which they are no longer capable of working. One high technology executive described his most recent startup experience thus:

> I put my three vice presidents in the hospital within the last two years, and three of the top four officers . . . lost their families through divorce in the past year. Suddenly you wake up an realize your kids are two or three years older, and one of them is in trouble.[24]

The Silicon Valley model of innovation thus can create enormous personal costs for its participants.

The more serious problem for the US economy, however has to do with the types of innovation that Silicon Valley can pursue and those that it cannot. As we described earlier the innovations that venture capital and entrepreneurs pursue are those taht will yield large capital gains in five to seven years. This means that the small incremental innovations receive little interest from venture capitalists and high technology engineers, and yet it is often these that make an important difference in the long-run success of companies in the marketplace. Effectively speaking, in such a system manufacturing becomes not a weapon of commercial success, but rather a necessary nuisance to be tolerated or turned over to

---

[22] For discussion of vulture capitalist see, John Wilson, *The New Venturers*.

[23] For more information see, William Sahlman and Howard Stevenson, "Capital Market Myopia," *Journal of Business Venturing*, 1, 1 (Winter 1985): 7–14.

[24] Everett Rogers and Judith Larsen, *Silicon Valley Fever*, p. 153.

original equipment manufacturers in Asia. The capital gains creation is in the intellectual property developed by the engineers and sold by the marketing experts.[25]

The other type of innovation that Silicon Valley is not equiped to undertake is what Hughes has called "systems" innovations.[26] These are innovations that require much more than the development of a discrete device to become functional. For example, to develop color television required not only a television, but also the development of new cameras and broadcasting equipment. Systems innovations require the operation of much larger teams of researchers and other personnel than does the development of a new personal computer, a biotechnology-produced pharmaceutical or a new type of integrated circuit. Also, for systems innovations huge capital investments are necessary before the product even comes to the market. These investments are far too big for venture capital and small companies to undertake. However, in the US the large companies find it increasingly difficult to coordinate and undertake such investments. Thus, the US as an economy is unable to pioneer megainnovations like the forthcoming high definition television.[27]

VII. *Conclusion*

We have shown that in the postwar period many of the giant US companies were increasingly unable to bring new innovations into the marketplace. This stifling of internal innovation did not prevent persons with new ideas from leaving and starting their own companies. These startups eventually created their own environment in Silicon Valley and Route 128. However, this entrepreneurial process was so successful financially that it became the focus of US innovation—the best electronic engineers and biotechnologists wanted to work for startups. This meant that the large companies would find it increasingly difficult to create organizational "self-renewal" internally.[28]

The US model of innovation employing small companies funded by venture capital has clearly allowed the US to develop technloogical breakthrough after breakthrough. However, merely being the first to develop a new technology or new device is not sufficient in this increasingly competitive world. Merely capturing the gains of innovation has not ensured US success. Japanese firms utilizing very different methods of organizing innovations and applying high technology have also reached the world standard. This is especially true in hybrid technologies such as mechatronics and optoelectronics.

In the last few years a number of the larger US firms scuh as Xerox, IBM and AT&T have attempted to create new environments for innovation in production through the use of quality control circles. However, it will be much more difficult for them to design the types of environments that will reward innovators and retain them within the company.

---

[25] This is a general critique and does not apply to every firm. Certainly, DEC, perhaps, Apple and some of the biotechnology companies such as Genentech have overcome this bias.

[26] Thomas Hughes, *Networks of Power*, (Baltimore: Johns Hopkins, 1983).

[27] Recent discussions have taken place between DEC, IBM, Apple, Intel, Zenith and others regarding the formation of a consortium to develop high definition television.

[28] For further discussion of the concept of "self-rebewal" see Ikujiro Nonaka and Teruo Yamanouchi, "Managing Innovation as a Self-Renewing Process," *Journal of Business Venturing* (forthcoming).

Yet, developing new methods of managing innovation inside the corporation may be necessary to ensure overall competitive success.

OHIO STATE UNIVERSITY AND CARNEGIE MELLON UNIVERSITY