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

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

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## 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

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[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).

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