Landmarks in our Understanding of the Management of Engineering and Technology

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Thomas Hughes

"We see, then, an aspect of technological progress – interconnected inventions and innovations advancing on a broad front of technology. Advanced and reverse salients on the front revealed needs and dictated the efforts of inventors, engineers, and industrialists."

The Development of Western Technology Since 1500, NY: MacMillan, 1964. (P. 7)

Dean Keith Simonton

"So far, nothing appears to impose any substantial constraint on the conclusion that scientific creativity functions like a chance combinatorial process. ….discovery and invention fail to operate as a straightforward, step-by-step, logical process."

Creativity in Science: Chance, Logic, Genius, and Zeitgeist, Cambridge University Press, 2004. (P. 96)

2197 entrants to auto industry of which 1427 newly formed, Carroll 1996

Industry origin data available	577
Bicycle manufacturing	44
Carriage manufacturing	126
Components	11
Dealers	26
Engine manufacturing	111
Other motor vehicles	76
Other industry	183

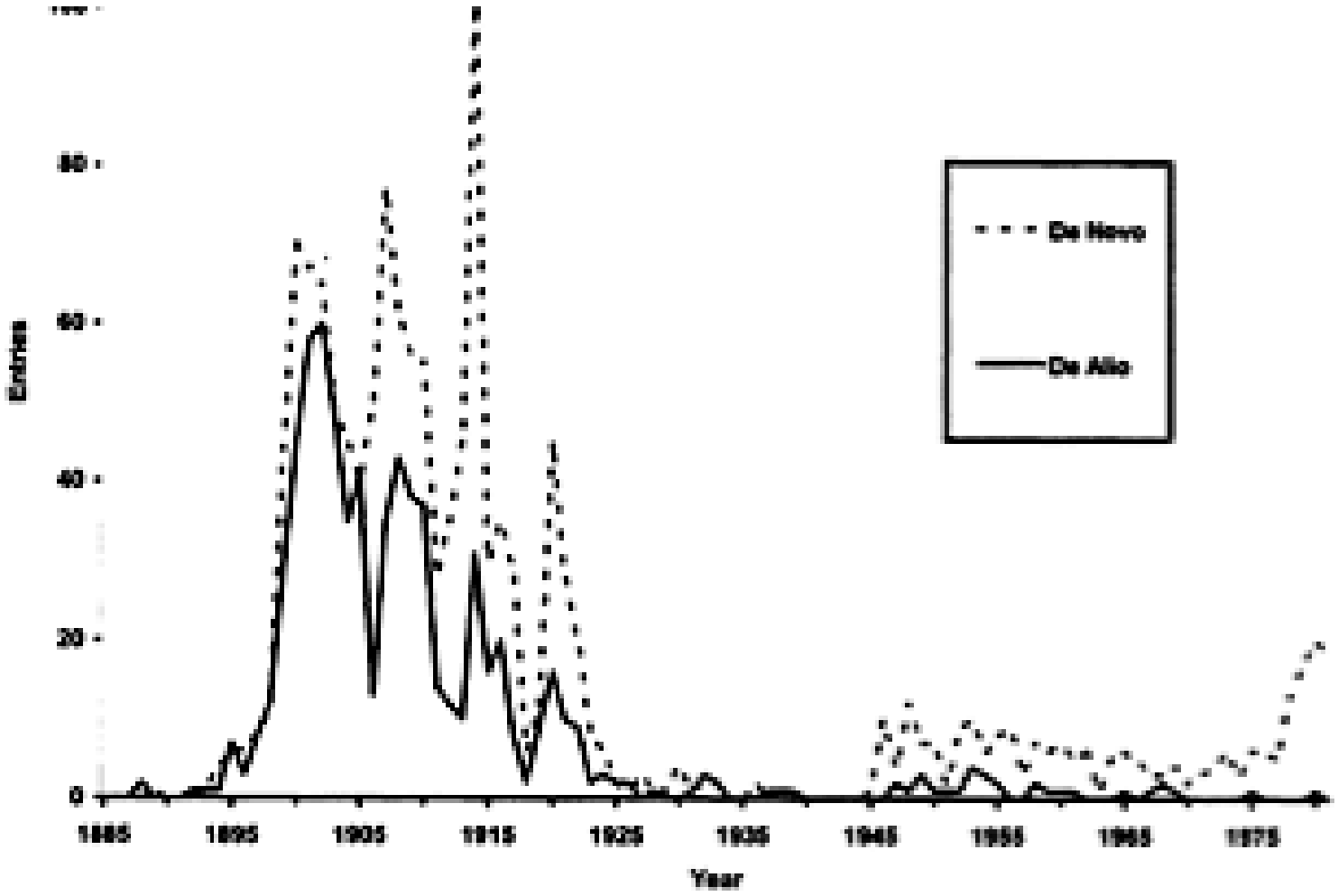


Figure 1. Entries of *de novo* and *de alio* American automobile producers

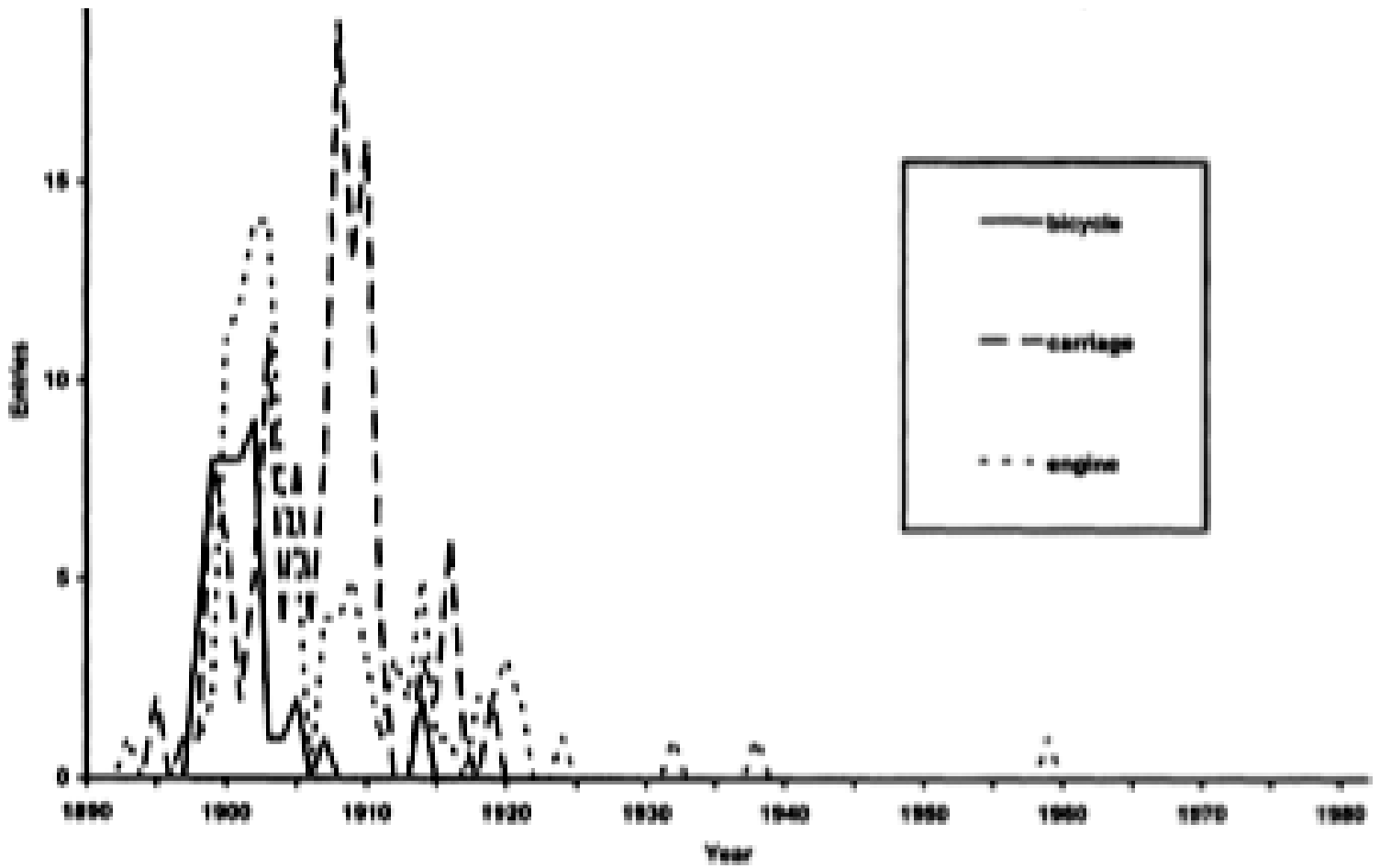


Figure 2. Entries of bicycle, carriage and engine manufacturers into automobile producti

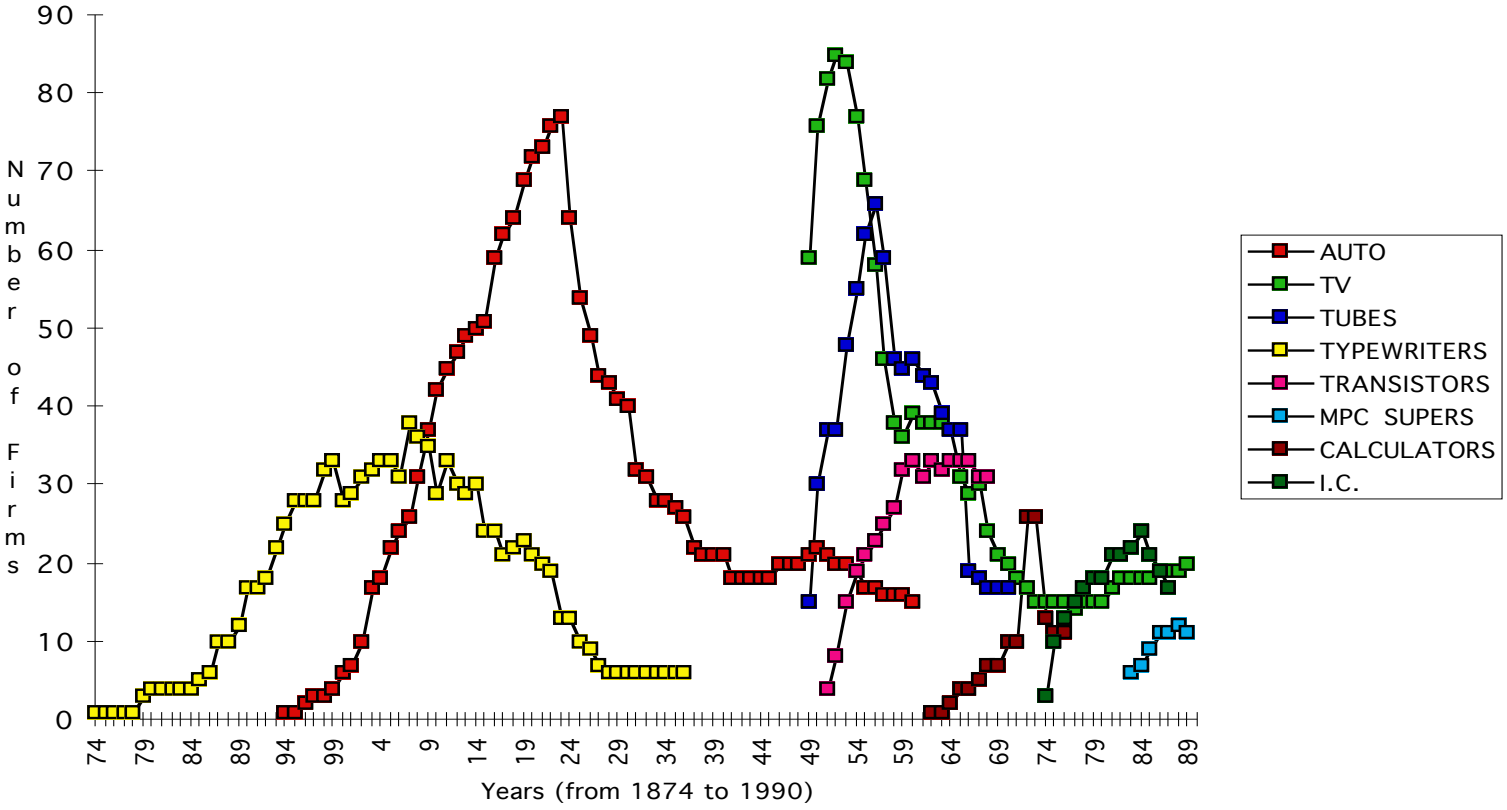
[e 7 Illustrates a potential problem of many commentaries' Barriers firms from a

William Abernathy

A dominant new product synthesized from individual technological innovations introduced independently in prior products has the effect of enforcing standardization so that production economies can be sought.

Patterns of Industrial Innovation, *Technology Review*, 80:1, June/July 1978.

Number of Firms in Several Industries



James M. Utterback and Fernando Suarez, "Innovation, Competition and Industry Structure," Research Policy, Vol. 22, No. 1, February 1993, Pp. 1-21.

Jun Suzuki and Fumio Kodama

"These results suggest a close relationship between internal technological diversity and the competitiveness of the firm….
In conclusion, case studies of persistent innovators have elucidated the importance of persistent knowledge accumulation in multiple technology fields in order to take advantage of cross-fertilization or synergy effects."

Technological diversity of persistent innovators in Japan: Two case studies of large Japanese firms, **Research Policy**, 2004, 33(3), 531-549.

Computer Memory Manufacturers: 1970

	Established Firms	New Firms
Core Memory	26	0
Plated Wire	8	0
Thin Film	5	1
Semiconductor	6*	7**
Totals	31	8

* includes IBM ** includes INTEL

Source: J.M. Utterback and J. Brown, "Monitoring for Technological Opportunities," Business Horizons, October 1972.

Jack Morton and Tom Allen

Information seems to be almost as reluctant to flow, as are people, and this may be because information moves most effectively when it is carried in person. It is easy to assume that information is always clear and codified. While this may be approximately true for some of the sciences, it is much less so for engineering and technology, and even less so for design and aesthetics. Indeed, most knowledge in these fields seems to be tacit, embedded in experiences and subject to interpretation. Thus, to communicate requires conversation, negotiation, modeling, drawing, demonstration, experiment, and explanation.

Jack Morton and Tom Allen

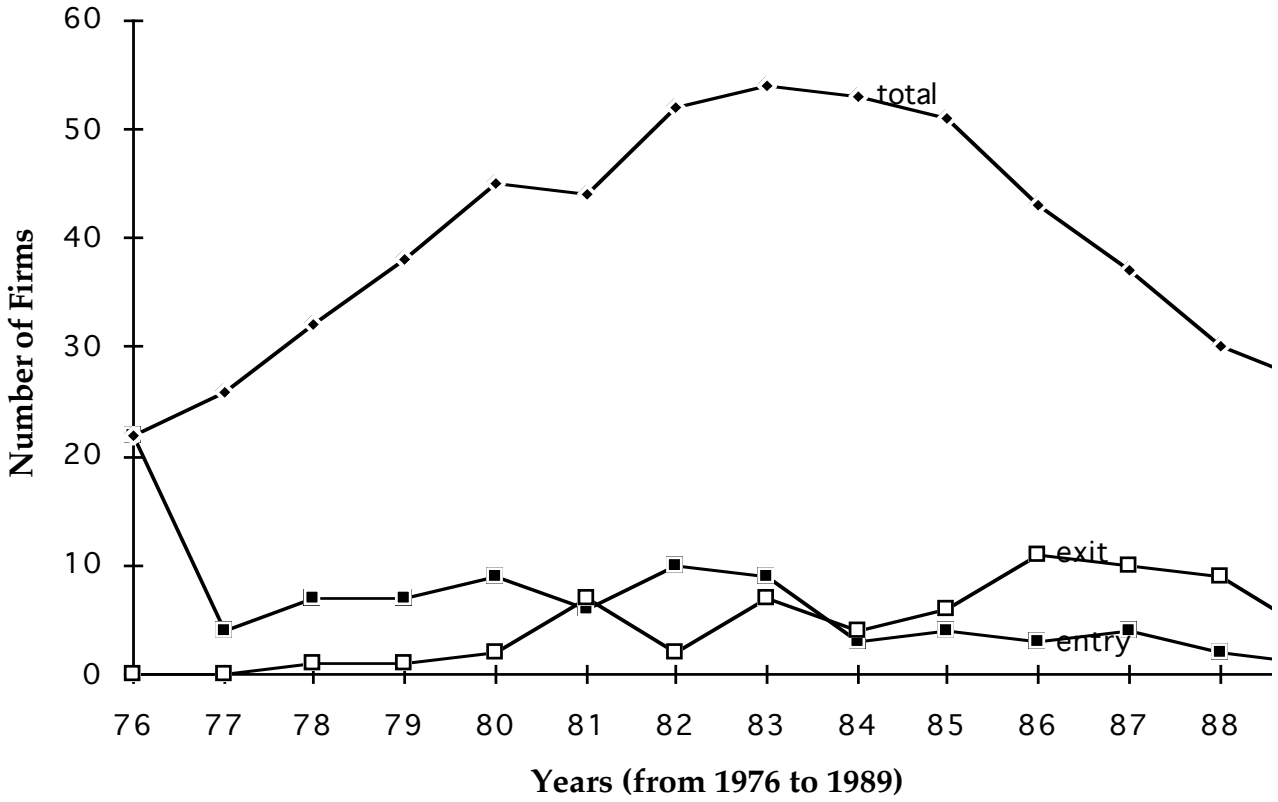
Tacit information is, by its nature, difficult to write down or index with precision. Hence, it is also difficult to possess exclusively, to appropriate, or to patent tacit knowledge. In a sense, it is within the state of the art. It is also clear that people tend to search for all information, and especially tacit information, first in their local neighborhood and among their closest and most trusted sources, reaching out further in general only when these do not suffice. Thus, we believe that the importance for the creative process of firms' proximity to one another is greatest when the information they require is tacit or rapidly changing.

Michael Bickard

Using instances in which the same discovery is made simultaneously in an entrepreneurial venture and at a large firm, the preliminary results indicate that entrepreneurs tend to disengage from projects involving too little uncertainty for fear of competition with companies that have much greater resources. On the other hand, larger firms tend to reject ideas with high uncertainty, providing space for young firms to grow, “sheltered from competition” by this very uncertainty.

Essays on the production and commercialization of new scientific knowledge, MIT thesis, 2013.

Number of Firms in the U.S. Rigid Disk Drive Industry



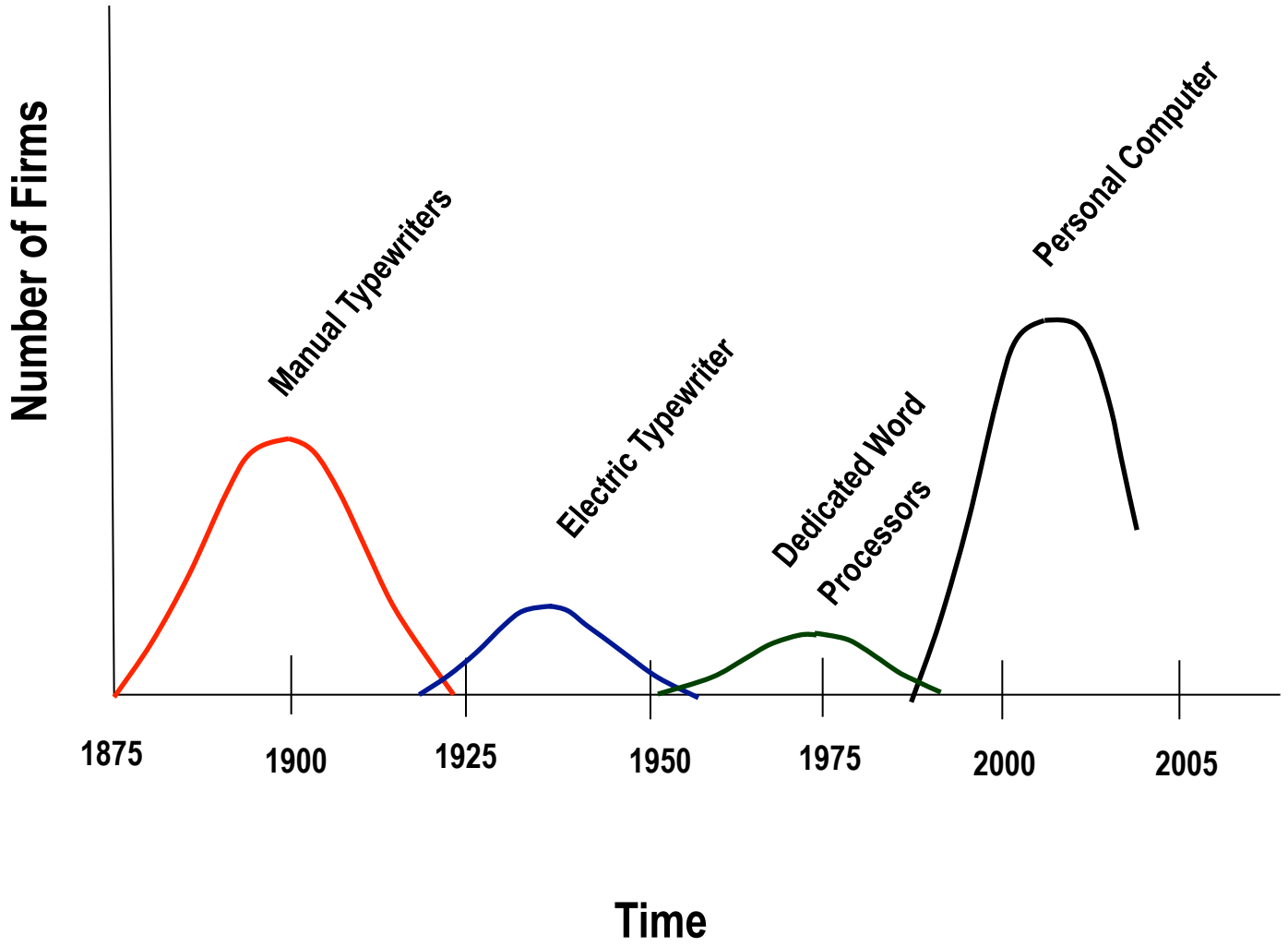
Christensen, Suarez and Utterback, 1998

Alfred Chandler

With each succeeding generation of a technology an industry will be composed to a greater extent by existing large firms moving from one generation to the next.

The Visible Hand, Cambridge: Harvard University Press, 1977.

Ecology of Business Succession



Source: Utterback, 2004 unpublished

Changes in Market Leadership -- Typewriter Industry

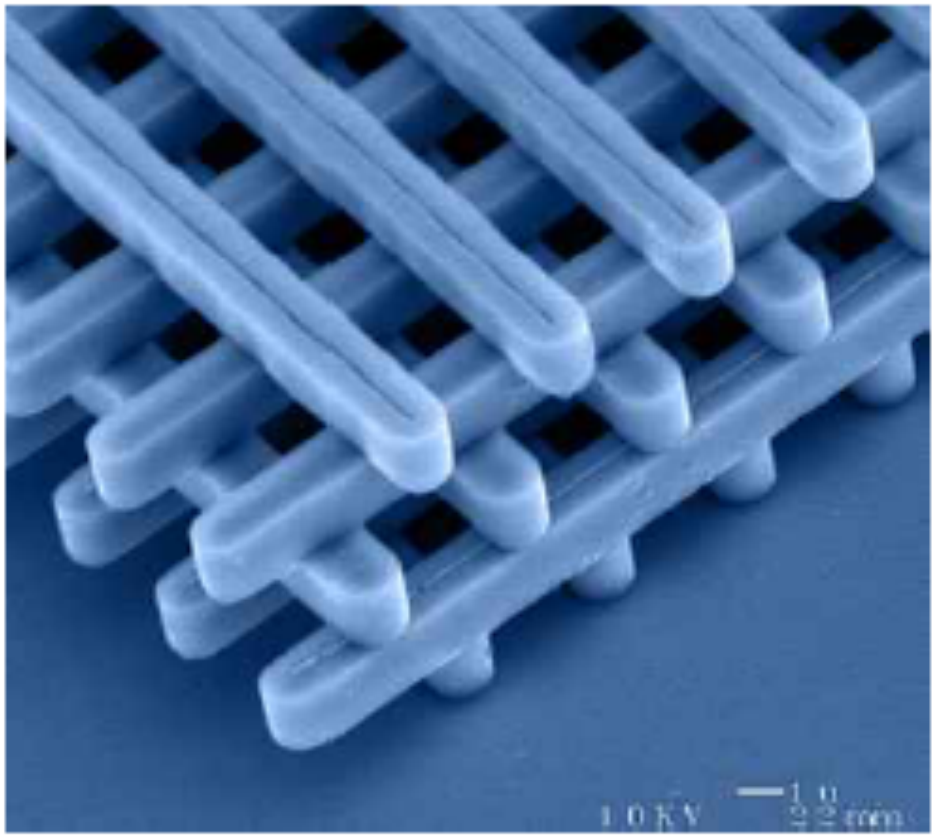
Product Generation:	Leading Firm:
Manual Office	Underwood
Electric	IBM
Word Processor	Wang
Personal Computer	Compaq

Source: Utterback, 1994

William Ward and James Bright

In the 50 years after the introduction of the steam ship, sailing ships made more improvements than they had in the previous 300 years. The term "Sailing Ship Effect" applies to situations in which an old technology is revitalized, experiencing a "last gasp" when faced with the risk of being replaced by a newer technology.

Ward, W.H. (1967). "The sailing ship effect," *Bulletin of the Institute of Physics and Physical Society* (18): 169.



Incandescent Innovation? – Tungsten lattice for entrapment of infrared radiation.

Source: (W. Keener editor, "In the Heat of the Light", Sandia Technology, vol. 4 no. 2, Summer 2002, pp. 5.)

Russell Ackoff

"Science formally separated itself from philosophy only a little more than a century ago. It then divided itself into physics and chemistry. Biology emerged out of chemistry, psychology out of biology, and the social sciences out of psychology…. Disciplines proliferated…. Disciplines are categories which facilitate filing the contents of science. They are nothing more than filing categories. Nature is not organized the way our knowledge of it is….
We need an extreme fusion of interdisciplines."

The Systems Revolution, **Long Range Planning**, 1974, 7(6), 2-20.