Landmarks in our Understanding of the Management of Engineering and Technology

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“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)
“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.”

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

Industry origin data available

Bicycle manufacturing
Carriage manufacturing
Components
Dealers
Engine manufacturing
Other motor vehicles
Other industry
Figure 1. Entries of *de novo* and *de alio* American automobile producers.
Figure 2. Entries of bicycle, carriage and engine manufacturers into automobile production illustrates a potential problem of many 'competencies'. Because firms from
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

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.”

## Computer Memory Manufacturers: 1970

<table>
<thead>
<tr>
<th></th>
<th>Established Firms</th>
<th>New Firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Memory</td>
<td>26</td>
<td>0</td>
</tr>
<tr>
<td>Plated Wire</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Thin Film</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Semiconductor</td>
<td>6*</td>
<td>7**</td>
</tr>
<tr>
<td>Totals</td>
<td>31</td>
<td>8</td>
</tr>
</tbody>
</table>

* includes IBM      ** includes INTEL

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.
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.
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.

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.

Ecology of Business Succession

Source: Utterback, 2004 unpublished
Changes in Market Leadership -- Typewriter Industry

<table>
<thead>
<tr>
<th>Product Generation:</th>
<th>Leading Firm:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Office</td>
<td>Underwood</td>
</tr>
<tr>
<td>Electric</td>
<td>IBM</td>
</tr>
<tr>
<td>Word Processor</td>
<td>Wang</td>
</tr>
<tr>
<td>Personal Computer</td>
<td>Compaq</td>
</tr>
</tbody>
</table>

Source: Utterback, 1994
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.


“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.”