Technology Management As A Cold War Construct

Stream 6: The Cold War and Management

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Abstract

The techniques of the field of ‘technology management’ include methods to monitor, forecast, classify and evaluate alternative technologies and methods to achieve portfolios of R&D projects to produce potentially relevant technologies. These techniques are underpinned by models such as the S-curve and by typologies such as ‘emerging, pacing, base and key’ to describe technology maturity.

While the problem that all these methods seek to tackle is the unpredictability of technology and the contingent ways in which technology becomes embodied and applied, the methods generally rely on formal methods to remove this unpredictability. Technology management textbooks describe ways in which technologies can supposedly be predicted. The methods include various forms of decompositional analysis, extrapolation and probabilistic modelling. In essence, the inherent unpredictability of technology is seemingly mitigated by analytical methods.

This view of technology and its ultimate tractability is at variance with an alternative, Schumpeterian, reading of innovation which has emphasised the disruptive and chaotic potential of new technologies. The question arises as to how the dominant literature of technology management has been constituted. This paper argues that many of the dominant paradigms in the field of technology management are historically and philosophically located in the US military industrial complex. Here, because large scale projects are run on long timescales, and because technologies are only slowly incorporated, it appears feasible to adopt these forms of forecasting. Furthermore, in this environment, the resources are available for the use of ‘brute force’ methods.

By contrast, the more recent approaches to technology management have accommodated the unpredictability of technology by placing greater reliance on enterprise, venture capital and market mechanisms to sort out one technology from another.

In essence, the field of technology management embodied approaches to technology and to problem solving which were characteristically those of the military industrial complex.
Introduction

Few would argue with the assertion that technological change is one of the principal
drivers of competition (Porter, 1985). The field of technology management -
alternatively referred to as management of technology (or MOT), or the management
of technological innovation (or MTI) - seeks to develop techniques by which technology
change can be managed. According to Betz (1998), the field is approximately 40
years old and seeks to (i) understand the pattern of change in the past due to the
technical bases of human activities, and (ii) use this understanding to improve
techniques for managing technical change in the future. The textbooks in the field
generally refer to the role of technology in economic growth and then go on to assert
ways in which firms can harness technology for competitive success, dealing with
practical problems such as technology selection, R&D management, and achieving
organizational integration between R&D and marketing. The field has also drawn on
other management ideas such as core competence theory (Prahalad and Hamel,
1990) and real options theory. A recurring theme in the field is the need for firms to
have methods to decide which R&D projects or technology innovations to invest in.
The literature abounds with methods to monitor, forecast, classify and evaluate
alternative technologies and predict their future progression. The latest in this line is
‘technology roadmapping’ (Probert and Radnor, 2003) which is a Delphi-like process
for coming to a shared view about technology and market futures.

This paper argues that the US military industrial complex, bound up with the Cold War,
has had a major influence in shaping this field. But by promoting a particular and
limited concept of technology and technological change, the field followed a path that
made it ill equipped to deal with the managerial issues around non-military ‘consumer’
technologies, particularly as they arose in the immediate post-Cold War period.

Contrasting Concepts of Technology

In the first part of this paper I want to contrast the ‘technology management’ paradigm
from the Schumpeterian paradigm. Table 1 summarises the analysis. The first
column shows the approach to technology first articulated by Schumpeter, but also
adopted to some extent by evolutionary theorists of economic change such as Richard
Nelson and Sidney Winter. The second column shows the dominant technology
management paradigm, pursued by many but associated over some years with small
number of US business schools, notably the MIT Sloan School (Ed Roberts, Tom
Allen, James Utterback, Eric von Hippel), Harvard Business School (Bill Abernathy,
Clayton Christensen), and Stanford University (Robert Burgelman) in the US.
Table 1. Contrasting paradigms of technology and its management

<table>
<thead>
<tr>
<th>Nature of technology change</th>
<th>Schumpeterian paradigm</th>
<th>‘Technology management’ paradigm</th>
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<tr>
<td>Nature of response</td>
<td>Revolutionary</td>
<td>Ordered</td>
</tr>
<tr>
<td>Unpredictable</td>
<td>Chaotic</td>
<td>Essentially predictable</td>
</tr>
<tr>
<td>Discontinuous</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nature of response</td>
<td>Entrepreneurial, risk-taking</td>
<td>Technical-rational</td>
</tr>
<tr>
<td>Key actors</td>
<td>Innovators and entrepreneurs</td>
<td>Top managers</td>
</tr>
<tr>
<td>Key concepts and methods</td>
<td>New combinations</td>
<td>S-curves</td>
</tr>
<tr>
<td>Innovation</td>
<td>Technology Trajectories</td>
<td>Technology taxonomies</td>
</tr>
<tr>
<td>Entrepreneurship</td>
<td>Technology forecasting</td>
<td>Decompositional methods</td>
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<td>Flow charts</td>
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The first axis of contrast is on the nature of technological change itself. The Schumpeterian paradigm sees economic progress as a series of ‘revolutions’:

The history of the productive apparatus of a typical farm, from the beginnings of the rationalization of crop rotation, plowing and fattening to the mechanized thing of today—linking up with elevators and railroads—is a history of revolutions. So is the history of the productive apparatus of the iron and steel industry from the charcoal furnace to our own type of furnace, or the history of the apparatus of power production from the overshot water wheel to the modern power plant, or the history of transportation from the mailcoach to the airplane. The opening up of new markets, foreign or domestic, and the organizational development from the craft shop and factory to such concerns as U.S. Steel illustrate the same process of industrial mutation—if I may use that biological term—that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism. It is what capitalism consists in and what every capitalist concern has got to live in. (Schumpeter, 1975)

The technology management paradigm sees beyond the apparent chaos to some sense of order and predictability. An example of how this predictability is expressed is shown in Figure 1, which is a forecasted technological map for 3-D holographic colour movies (Goodman and Lawless, 1994: 86). The timing of technology transitions may be uncertain but not entirely so. Technology is expected to follow an S-curve, an identifiable pattern showing how the performance of a given technology changes over time (Foster, 1986). According to Christensen (1997), the technology S-curve forms the centrepiece of thinking about technology strategy. Technologies are presumed to
follow trajectories which allow past changes in performance to be extrapolated into the future.

The second axis of comparison is the nature of the managerial response. The Schumpeterian paradigm relies on human agency in the form of innovators and entrepreneurs, seeking both 'new combinations' and a period of supernormal returns consequent on leading disruptive change. The technology management paradigm by contrast demands a technical-rational response in which technological change is forecasted and managed.

Figure 1. Forecasted technological map for 3-D holographic colour movies (Reproduced from Goodman and Lawless, 1994: 86).

The key actors differ too. Schumpeter asserted a central role for innovators and entrepreneurs in bringing new technologies to market. By contrast, technology management addresses managers and strategic decision makers.

Schumpeter’s paradigm is primarily descriptive and has not given rise to methods, save the need to encourage entrepreneurial behaviour. By contrast, the technology management paradigm embraces a range of techniques and methods. Many involve finding pattern in the chaos of technological change. The S-curve referred to earlier is one such pattern. Superimposed on this is the idea of intersecting S-curves, whereby one technology takes over from another.
Technologies differ in their impact on a business. One schema for analysing technologies, promoted by Consultants Arthur D Little, is based on classifying their competitive impact into four or sometimes three levels, namely: pacing, key, base and emerging. (Roussel et al, 1991: 64). These terms are defined in Table 2.

Table 2. Arthur D Little’s technology classification

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
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<tr>
<td>Base</td>
<td>Although essential to the business, these technologies do not provide significant competitive advantage.</td>
</tr>
<tr>
<td>Key</td>
<td>These technologies are critical for today’s bases of competition.</td>
</tr>
<tr>
<td>Pacing</td>
<td>Although not fully embodied in current products, these technologies may, if successfully applied, have a substantial impact on the basis of competition in the reasonably near future.</td>
</tr>
<tr>
<td>Emerging</td>
<td>These technologies may have an impact on competition in the future but this is far from certain.</td>
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These descriptions apply to ‘technologies’, not whole products or systems. So products or systems need to be decomposed into their technology elements. Decomposition is a recurrent theme through the methods of technology management, the idea being that big problems can be decomposed into smaller elements and that these smaller elements can be separately addressed prior to being re-integrated. For example, almost one hundred ‘technologies’ are neatly listed as necessary for the production of electronic components, for example (Goodman and Lawless, 1994: 74). These technologies are the ones that need to be mastered for a company to participate in the electronic components industry. A variant on this form of taxonomy is the relevance tree. Twiss (1980: 77) describes the use of relevance trees in technology forecasting and comments that:

This technique can lead to highly complex computer-based approaches. In the Honeywell Pattern program, all military and aerospace activities in which the company was or could be involved were covered. The cost of setting up this program has been estimated at $250,000 to $300,000 with a further annual running cost of $50,000. Relevance trees have also been used by the British Post Office R&D department for relating the choice of projects to the organisation’s objectives. The scale of effort involved in Pattern should not however deter the industrial R&D manager with limited resources at his disposal.

Technology management methods frequently make use of complex flow charts. Figure 2, reproduced from an influential book by Roussel et al (1991: 154) deals with the relation between project management and strategic planning). Figure 3 shows the stages in technology mapping; Figure 4 shows a technology diffusion map.
Figure 2. Linking strategic planning to project planning and execution (Reproduced from Roussel et al, 1991: 154)

Figure 3. The seven steps of technological mapping (Reproduced from Goodman and Lawless, 1994: 104)
Figure 4. An example of a technology diffusion map (Reproduced from Goodman and Lawless, 1994: 83)

Flow charts such as these display the ordered way in which the technology management paradigm represents the world. These sorts of decompositions, flow charts and formalisms are often elaborate. When applied to real situations, they are normally data-hungry because each one of the decomposed elements of a complete product or system needs to be separately analysed. This complexity is no doubt beneficial to the consultancies that have sold projects which use these methods; the authors of Roussel et al (1991) worked for US consultancy Arthur D Little. Flow charts and formalisations such as these are not uncommon in other fields of management. But the contrast between the discontinuities of technology observed by Schumpeter and these confidently asserted analytical methods is striking.

In essence, technology management is treated in this paradigm as a technological problem rather than a sociological one. Marshalling the methods of engineering, and given sufficient effort and an appropriate method, the paradigm promises that the path of technology can become calculable and that the uncertainties can dissolve away.

The Cold War Character of Technology Management

The methods of technology management are, as indicated above, often elaborate and data-hungry. This characteristic is immediately indicative of some limitations on the domains of applicability of these methods. Firstly, the technologies must be sufficiently
slow changing that their trajectories can reasonably be plotted. This implies a context within which technologies and their eventual embodiment have significant inertia. Second, the scale of the technology management decision must be large enough that the time and expense of using these methods is conceivably warranted by the improved result. Thirdly, the product or system being managed must be highly influenced by its technologies, as opposed to market or marketing issues. Indeed, few of the methods even deal with market uncertainty.

These three aspects of the paradigm are indicative of the sorts of projects undertaken by the US military industrial complex. The lifecycle of military development projects can be so long that it is feasible to undertake this sort of planning. Interestingly, though military systems are sometimes at the forefront of technology, their long lifecycles can result in them being outdated. For example, the US SAGE early warning system, which operated using vacuum tubes, was still operating in 1983 (Edwards, 1996: 108). The scale of the decisions being made, and the consequences of failure in terms of wasted resources, can be so high that these expensive methods appear worthwhile. Being so elaborate, the resources for formal technology management methods were more likely to be found within the military context than elsewhere. Finally, because of the close coupling between the buyers of military systems and their manufacturers, many of the market uncertainties of consumer product innovation are not present in the military context.

Overall, then, the methods of technology management are more applicable to the type of product development processes in large military projects than they are to consumer products.

The methods also embody a philosophy that is located in the thinking of the Cold War period. They assume a level of calculability which resonates strongly with what Edwards (1996: 15) calls "closed-world discourse" of the Cold War. Edwards argues that the Cold War was inseparable from the computers that made it possible and shows the pervasive role of elements such as:

- Techniques drawn from engineering and mathematics for modelling aspects of the world as closed systems.
- Technologies, especially the computer, that make systems analysis and central control practical on a very large scale.
- Practices of mathematical and computer simulation of systems such as manufacturing processes and nuclear strategy, in business, government and the military.
- Experiences of grand-scale politics as rule-governed and manipulable, for example by means of the power of nuclear weapons or of Keynesian economic intervention.
- Fictions, fantasies, and ideologies, including such visions as global mastery through air power and nuclear weapons, global danger from an expansionist "evil empire," and centralised, instantaneous, automated command and control.
- A language of systems, gaming, and abstract communication and information that relied on formalisms to the detriment of experiential and situated knowledge. This
language involved a number of key metaphors, for example that war is a game and that command is control.

As we have seen, some of these elements are present in the field of technology management. Edwards’ first element is concerned with forms of modelling drawn from engineering and mathematics. The role of decompositional methods in technology management was explored above, and decompositional approaches are indeed widely used in engineering and applied mathematics. For example, in the technique of finite element analysis, a complex structure such as an aircraft wing is broken down into many separate elements. Calculations of stress and strain are then made for each element. Finally, the calculations of the individual elements are combined so that the response of the structure as a whole can be determined.

Edwards’ second element is concerned with the way in which technologies make forms of central control practical on a large scale and his final element is concerned with the way in which experiential and situated knowledge is weakened under the weight of formalisms and abstract communication. Technology management techniques, because of their expense and complexity, are often sponsored by the top management of companies, and are sometimes utilised as a method to shift power away from R&D or technical specialists whose knowledge is typically more experiential.

Edwards recounts the way in which Robert McNamara approached technology procurement for the Pentagon. McNamara adopted a systems analysis perspective in which complex choices could be decomposed into elements or steps, each one of which was ‘a problem of reasonably finite dimensions which are measurable’.

The Cold War influence

This paper has, until now, concentrated on showing relationships between technology management and the Cold War context but not demonstrating how such influence occurred.

Technology leadership and military leadership have been coupled in US policy since World War II. One of the most influential policy documents in shaping the US research base was Vannevar Bush’s 1945 report to President Truman, Science – The Endless Frontier, which began by stating the fundamental importance of basic research to achieving vital national goals (Smith, 1990: 43):

Progress in the war against disease depends upon a flow of new products, new scientific knowledge. New products, new industries, and more jobs require continuous additions to knowledge of the laws of nature, and the application of that knowledge to practical purposes. Similarly, our defence against aggression demands new knowledge so that we can develop new and improved weapons … [because] with-out scientific progress no amount of achievement in other directions can insure our health, prosperity, and security as a nation in the modern world.
This sets the scene for the now familiar technology race. But the case for technology management can be made in the same terms, as the preface of Burgelman and Maidique’s 1988 textbook of technology management shows:

> What concepts, techniques, facts, and management processes result in successful technological innovations? [...] These concerns are, however, of relatively recent vintage. For decades after World War II it appeared that America would reign indefinitely as the world's technological superpower. This fantasy has been shattered by the industrial recovery of Europe and the rise of the Japanese as an economic and technological superpower. Both Japan and Europe have made major inroads into industries that were once considered unassailable U.S. strongholds. At first it seemed that the challenge was mainly in the traditional capital-intensive, heavy manufacturing industries such as steel and automobiles and in consumer electronics. In the 1980s the challenge broadened to include all aspects of electronics, including semiconductors as well as aerospace products and telecommunications. These developments have made effective technology management a high-priority issue for U.S. business. (Burgelman and Maidique, 1988).

In this way, technology management is coupled to the standing of the US as a superpower.

The diffusion of military technology management techniques into the non-military sphere is illustrated by a paper by Bird and Darracott (1968).

> During the mid-1950s, many people who were intimately concerned with research and development in the Army became painfully aware that planning methods were inadequate. In an age of increasingly complex and sophisticated weapons, newly developed systems often cost more than anticipated. The time elapsing between recognition of a technical capability and development of a system was unacceptably long. It was found that these difficulties were primarily due to two causes. (Bird and Darracott, 1968: 385)

Bird and Darracott went on to describe the way in which the component capabilities required in these new systems were sometimes beyond the state of the art. The new components would have new characteristics which then affected other interrelated components and subsystems, leading to an expanding process of research and component development.

The US Army was working on technological forecasts in the 1950s. In 1957 the Ordnance Corps compiled a Technical Capabilities Forecast FY 59-70. Later, the process for producing consolidated Long Range Technological Forecasts became established. The forecasts fed into other forms of strategic planning, described as a ‘family of plans’.

Bird and Darracott conclude as follows:
The analogy between the problems of the Army and those of industry should be apparent, and some of the lessons learned in developing the Army’s research and development planning system should be useful to industrial management. The basic ingredients—a set of broad, long-range objectives and a forecast of the possibly useful technological potential, each developed separately and neither one constraining the other’s imaginative development, but instead continuously providing inspirational guidance to the other—appear equally applicable to planning a company’s future products. The continuous interchange of ideas between people cognisant of the potential of technology and people capable of estimating future marketability, both working within the constraints of, and inspired by, broad company objectives, can provide a basis for company planning. Just as the Army tries to look ahead as far as twenty years in developing its objectives and forecast, so a company should look far enough into the future to allow time for the development of its future products and their markets (Bird and Darracott, 1968: 411).

Another perspective is based on the volume of defence research as a proportion of the total. Over the entire post war period defence research has constituted over 50% of all federal research, which itself is between one-half and two-thirds of all R&D in the US (Table 3). Nearly 80% of all federal R&D in 1984 went in to just two industry sectors—aircraft and missiles.

Table 3. US Military R&D Spending

<table>
<thead>
<tr>
<th>Year</th>
<th>All R&amp;D</th>
<th>Defence</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>13523</td>
<td>6100</td>
<td>45%</td>
</tr>
<tr>
<td>1970</td>
<td>26134</td>
<td>8000</td>
<td>31%</td>
</tr>
<tr>
<td>1980</td>
<td>62594</td>
<td>15100</td>
<td>24%</td>
</tr>
<tr>
<td>1990</td>
<td>132350</td>
<td>44000</td>
<td>33%</td>
</tr>
</tbody>
</table>

Source: Mowery and Rosenberg (1993)

This picture is true down at the level of individual industries. Mowery and Rosenberg (1993) looked at the semiconductor industry. Only by the end of the 1960s did the computer industry displace the military as the largest end user market for integrated circuits.

The preponderance of defence R&D no doubt meant that many of technology management problems originated out of the military industrial complex, and had to be tackled within the same context.

Discussion

Technology management developed as a field at a time when the business management of technology was largely, though not overwhelmingly, one of military-technology management. The field acquired a character which was closely linked to the large scale ‘closed world’ discourse of the Cold War. Fundamentally, technology
management was treated as a technological problem, to be solved with the tools of engineering. The messy world of humans, markets and organisations was either squeezed into the technical-rational frame, or ignored. The result was a field which was largely unrelated to the Schumpeterian understanding of the discontinuous nature of technology and the centrality of innovators and entrepreneurs in technology development and commercialisation.

The consequence of this thwarted development is that the field of technology management was in a poor position to address the managerial issues associated with fast moving consumer products. In contrast with his upbeat message in 1980 (Twiss, 1980), by 1992 in a revised edition of the same text, Twiss (1992: 294) commented that:

Most of the initiatives in technology forecasting originally came from the USA where several major companies invested heavily in it. There is some doubt whether the results justified the substantial investments.

More recent approaches to technology management have placed less reliance on the technical-rational methods questioned by Twiss. Post-Cold War methods are distinctly less technocratic; thus technology roadmapping (Probert and Radnor, 2003) is described as a team learning approach to develop a shared view among stakeholders about where they want to go. The national innovation agenda is seen less in terms of effective technology management and more in terms of interventions such as encouraging enterprise, ensuring open access to venture capital, and promoting spin-outs and start-ups. These are more in keeping with Schumpeter’s ideas.

While it would be too sweeping to argue that the technology management paradigm described in this paper stands as a Cold War relic, it was nonetheless rooted both practically and ideologically in the Cold War and the US military-industrial complex. The demise of the Cold War seems to have been accompanied by a change of direction for technology management.
References


