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Looking Ahead: **Fourteen Technology Trends**

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AMONG THE HUNDREDS OF TRENDS IN TECHNOLOGY that I have been able to detect over the past decade, I have found 14 that strike me as general across all fields and rich in their implications for strategic planning. These 14 are discussed below, with emphasis on the implications for R&D management.

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1. Technology is becoming more systemic, that is, attentive to the total system it draws upon and relates to, from raw materials to final waste disposal

One sees this today in the exploding interest in supply chain management. It also shows up in the expanding considerations shaping manufacturing, first integrating manufacturing with automation, and then with design, with after-market services, with raw material choices, and continuing all along the way to becoming more aware and responsive to current and potential legislation and social trends, including customer preferences.

Implications: *Is your R&D based on truly systemic considerations and developments?*

2. The distinction between science and technology is blurring

Through the early 20th century, invention stimulated scientific attention to promote efficiency and effectiveness, through better theory. Since about 1940, the relationship has been reversing, with basic science now leading to many new technologies. This is especially clear in genetics, brain science, biology, materials, and continuing briskly in information technology.

Implications: *What are your research programs concentrating on? How effective is your internal or external monitoring of scientific and technological developments directed at the next 10 to 15 years of applications?*

3. R&D is more interdisciplinary and cross-disciplinary

Historically, the development of the S&T disciplines centered around assumptions like Newton's three laws, which more or less ignored chemistry, strength of materials, user behavior, and scores of other areas. These simplifying models, relative to specific technologies, were very productive but eventually led to calling on other disciplines for deeper understanding and better products.

Most of the productive activity today occurs at the interface or conjunction of two or more disciplines. This is reflected in the many hyphenated professions like bio-geologist, and new umbrella fields like astrophysics. This trend reflects both the limited productive potential of individual disciplines and the growing complexity of technology.

Interdisciplinarity also arises to deal with complexity. An interesting illustration of cross-disciplinary thinking is to recognize that all organisms in nature are part of a complex ecology. It is equally clear that each molecule within a stem cell is in an enormously complex environment. We now see the emergence of a field, "stem cell ecology."

Implications: *Do you have the staff first to understand, second to draw upon, and third to implement technological interdisciplinarity? If not, you had better hurry!*

4. Globalization of all commercial, scientific and technological activities is just beginning

This implies, at a minimum, A competing in B's country, B competing in A's country, and B competing in C, D, E... .

This involves, at a minimum, exposure to new ways of doing things, new values and new business practices. It makes the technological workforce completely mobile internationally. However we will see the downside of untrammeled international commerce increasingly limited by regulation and practices that prevent businesses from arbitrarily changing venues merely to acquire low-cost labor at the expense of domestic labor. We will also see a widening public discussion in the advanced nations about how to better maintain a steady but less disruptive transition to a truly global economy.

Implications: *Has your firm or industry developed a position on globalization that goes beyond the narrow interests of your business or industry, i.e., the short-term concentration on profit?*

5. Outsourcing is a big step toward demonstrating and developing the virtual corporation

In its final form, the virtual corporation will have a tiny staff, an enormous amount of money, and perform three functions: planning, collaboration and money management. As the outsourcing trend continues, there seems to be no limit to what may be outsourced.

Each new move in that direction is a living experiment and a learning exercise in becoming virtual. There are unequivocal examples of the outsourcing of research, development, testing, evaluation, pilot activities, field research, components manufacturing, and total product manufacturing.

Implications: *How virtual could your firm become? By what mechanism and with what consequences?*

6. The secondary effects of a new technology tend to become more important than its anticipated marketing goals

Business has generally not been interested in the after-sales consequences of what it sells, except insofar as they suggest product improvement or changing marketing strategies. No computer manufacturer ever told its customers that they would virtually wipe out the secretarial pool and have the professionals and non-professionals alike keyboarding. Similarly, the developers of the Internet never alerted anyone to gambling, hacking, blogs, terrorist planning, or game playing and its effect of promoting childhood obesity.

Implications: *What will be the secondary effects of the new products you are developing? Incidentally what have been the principal secondary effects of the products you sold during the last 20 years?*

7. Physical technologies are still the most important ones in economic, social and personal significance

But biotechnology is growing rapidly in importance. The emergence of the concept of intellectual property and its expansion to include institutional practices is a sharp, deep wedge opening our recognition of social technologies as opportunities for clear and explicit invention.

Implications: *Which biological developments could threaten, compete with, or enhance your physical product or services? Which social technologies could benefit you?*

8. Competition by substitution is growing in all areas

The substitution ladder includes raw materials, parts, components, devices, sub-systems, systems, and macro-societal systems. One consequence is that there is an ever-widening range of choices for satisfying any technological need or opportunity. Most R&D attention is focused on the first few steps of the substitution ladder. But in the long pull, systems replacements will garner the greatest revenues and have the broadest effects, e.g., new sources of energy, new modes of water management, and new building design. Less attention is paid to systems competition because the higher up the ladder one goes, the greater the discontinuities will be in products, processes and components that one must accommodate and that require the greatest capital risks.

Implications: *At what step on the substitution ladder are you competing? What are the likelihood and the consequences of your moving up one or two steps?*

9. Information technology continues to force changes on individuals, families, businesses, organizations, governments, and international affairs, while improving efficiency and reliability, and increasing breadth and depth of knowledge

Virtually every large organization is now primarily an information machine and more like every other large organization than it was decades ago, when it specialized in selling specific products or services. To test this concept, draw a functional box diagram of your enterprise and ask the question, What percentage of decisions in each box is primarily based upon information?

Access to information about each enterprise is becoming increasingly open and available, sometimes through explicit policies of open access, but more often from the activities of public interest groups, the media and blogs.

The automation of R&D has made it enormously more productive and radically altered the time spent on different tasks by laboratory personnel. Finally, ironic as it may be, as technological knowledge rapidly expands, the public knows less and less about more and more of how its world works.

Implications: *Are you helping or hindering the informatization of your firm? Are you positively promoting more public openness, or leaving that up to your critics? How are you promoting public understanding of the technologies that you use, market, service, or plan to develop?*

10. Creativity is increasingly in demand

Nevertheless, we have few policies within organizations that exploit the substantial body of information we have about creative people and creative environments. For example, we can design laboratories that physically require people to come into contact and thereby promote direct personal exchange, recognized as a stimulant to creativity. There are new tools such as TRIZ that allow people to reach out to entirely unfamiliar domains and search for solutions to technological problems.

Implications: *How exactly are you promoting creativity? What were your two most important creativity-enhancing management innovations in the last five years?*

11. Fusion of technologies continues

Fumio Kodama, the Japanese science policy guru, years ago pointed out that great new benefits from technology would primarily occur by fusing, that is, combining or bringing together, independently-developed technologies to create new capabilities. The most conspicuous example of this is everything becoming "smart" by acquiring its own microchips. The concept applies to many other marriages of technologies but needs to be pushed more broadly and creatively.

Implications: *With what other technologies could your technologies be fused?*

12. New technologies will continue to create new risks

Emerging from the complexity of new developments, the personal—that is, individual—risks may be subtle and idiosyncratic, as with drugs. The risks may be more complex, after environmental exposure, as from pseudo-estrogens in drinking water. They may be more questionable and uncertain, as with the mental effects of cell phones. They may involve short vs. long-term trade-offs, as in impairment from loud music or the lift from smoking a cigarette.

New systemic risks come from the complexity of technology and the failure, based on misapplied cost-effectiveness, to protect against hackers, electrical network power failures, accidental events (e.g., train derailing) or planned disruption by terrorists.

Implications: *Do you have a business practice system and model for anticipating the risks from current or new technologies that you use, supply or service?*

13. Venture capital is highly important in the United States and of growing importance in Europe in funding new technologies, particularly those coming out of advanced science

The primary advantage of venture capital as practiced in the U.S. is to force the scientist-technologist--inventor to develop an outstanding business plan. The primary disadvantage of venture capital is that it is impatient money seeking short-term payoffs and is to some extent risk-averse.

Implications: Have you tried a venture capital model within your firm, in going from research concept to market?

14. Defense, Homeland Security, and NASA are growing forces in United States R&D

While this will undoubtedly bring us benefits in electronics, materials, clothing, food, and other areas, the question must be asked about which important R&D areas will of necessity be neglected.

Implications: *Which fields of concern to you receive relatively little government R&D support, directly or indirectly, because of this triad of dominance?*

A Charge to R&D Leaders

The boundless technological opportunities lying ahead will only be realized when R&D leaders break their shackles of intellectual constraint and systematically explore the universe for new possibilities, new ways of doing things, new products, and new services—and make this search a routine part of their organizational responsibilities.