

"The speculative world of emerging technologies"

by Stephen Hilgartner and Bruce V. Lewenstein

Cornell University

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In this election year, both Republicans and Democrats are depending on the rapid development of technological solutions to social problems. Nor are the political parties alone. Each year, hundreds of conferences, workshops, and articles highlight new developments in information technology, life sciences, and nanotechnology that may soon reshape the world. Consultants, academics, and futurists try to anticipate the possibilities of these emerging technologies, assess their benefits and risks, weigh their ethical dilemmas, model their environmental impacts, and calculate their economic effects and investment opportunities. One day the topic is autonomous vehicles, the next it is self-cleaning glass, and the following day it is individually-targeted genomic medicines.

But amid all the excitement about specific technological advances, it's easy to lose sight of how emerging technologies are more than particular new techniques and tools. Rather than viewing them simply as a collection of specific examples (valuable though that is), much is to be gained by seeing them also as a general phenomenon. From this perspective, what is most striking is that "emerging technologies" have become a distinctive social world, a peculiar "speculative space" found at the edges of technological systems, where innovations are being most actively constructed and transformed. In this dynamic space, emerging technologies exist in a state of flux as a mixture of blueprint and hardware, plan and practice, the nearly on-line and the almost obsolete, surrounded by speculation and speculators, who make often-contested claims about their promises, perils, and possibilities.

As the historian Michael Fortun has pointed out, financial speculation, entrepreneurial enthusiasm, and scientific uncertainty coexist in a world where claims about technologies that have yet to materialize remain fundamentally unverifiable. In a social world of prophecies intended to become self-fulfilling ("biotechnology will feed the world") or self-negating ("biotechnology will cause ecological havoc"), the speculative space becomes a site of ongoing institutional innovation and frequent public controversy, raising complex policy issues and problems of political legitimacy. To understand the space requires attention to its rhetoric, to technological practices, to institutional arrangements, and ultimately to the intersection of politics and ethics.

1. Revolutionary rhetoric

The term "emerging technologies" is less a tightly-defined concept than a flexible rubric, or even a slogan, used to signal the expectation of significant technological change. At times the term designates not a technological domain but a dynamic economic sector, energized by intensive R&D and fierce competition. In public discourse, the notion of "emerging technologies" lacks specificity but conveys unmistakable connotations of revolutionary potential. The familiar ambiguities of the term "technology" (which can encompass artifacts, techniques, skills, systems, networks, infrastructures, managerial practices, living things, organizational forms, etc.) are compounded by the adjective "emerging," which throws a dose of speculation into the mix. In journalism, industry forecasts, and policy documents, the concept usually designates a technology that is new, incompletely developed, a topic of active research, and expected to become very important. Emerging technologies are often described as "fundamental," "enabling," or "revolutionary" to contrast them with more "routine" innovations. A 2003 article in *Technology Review* entitled "10 Emerging Technologies That Will Change the World" captures the spirit of the concept:

In labs around the world, researchers are busy creating technologies that will change the way we conduct business and live our lives. These are not the latest crop of gadgets and gizmos: they are completely new technologies that could soon transform computing, medicine, manufacturing, transportation, and our energy infrastructure.

The article listed examples—such as wireless sensor networks, injectable tissue engineering, nano solar cells, and molecular imaging—arguing that each stands on the cusp of making its mark on the world. Beyond such specific technologies, the term "emerging technologies" also designates much broader technological domains, such as biotechnology, information technology (IT), or nanotechnology, often described in revolutionary terms. The notion of rapid and revolutionary change is also pervasive in business writing, where "emerging technologies" may designate an economic sector or type of firm. For example, business school professors George

Day and Paul Schoemaker argued recently that managing emerging technologies is "a different game," marked by "great uncertainty and complexity," "a fog of ambiguity," "accelerating change," and the challenge of "developing new competencies." Citizens who want to grasp the messy world of emerging technologies need to train their ears to the language of technological revolutions.

Ironically, the notion of revolutionary potential inspires both the breathless enthusiasm and the intense opposition that emerging technologies generate. For example, supporters and critics alike often describe biotechnology using stories of a sharp break from the past. Thus, supporters claim that biotechnology will completely transform agriculture, medicine, and pollution control, producing unprecedented improvements in human health and well being. Simultaneously, critics warn of unanticipated consequences and the hazards of entering a new stage of evolution in which life itself comes under technological control. Yet both groups also sometimes tell stories about biotechnology that highlight continuity with the past. Supporters of agricultural biotechnology may play down the novelty of genetically modified crops, presenting them as merely the latest twist on age-old techniques of plant breeding; opponents of ag biotech suggest that GM crops will perpetuate long-standing inequalities in agricultural systems. As this example suggests, these stories provide alternative perspectives that proponents and opponents can mix and match to mobilize support for their positions.

It's useful to read the revolutionary language critically, to understand how it is used. In a world in which start-up companies, research programs, and social causes are all aggressively marketed using a rapidly-expanding repertoire of communication technologies, discussion of emerging technologies is replete with promotional rhetoric. Amid scientific and social uncertainties, a variety of commentators fill the unavoidably speculative space with claims about "promise" or "peril." Moreover, the uncertainties often interact with the self-interest of the speakers, who seek to shape the future by promoting particular visions – both positive and negative – of the technologies. It may be tempting to dismiss these claims as "hype," "vaporware," or "fear mongering," but a healthy skepticism about the revolution of the week should not blind us to the significance of revolutionary rhetoric.

How deeply embedded is this rhetoric in our society? Fortun argued in a 2001 article in the aptly-named *New Genetics and Society* that "hype" cannot be eradicated from a world of "forward-looking statements," "anticipatory judgments," and "contingent futures," grounded in "a logic of speculation":

Just as there can be no truth without fiction, . . . there can be no science without speculation, there can be no economy without hype, there can be no "now" without a contingent, promised, spectral and speculated future. "Hype" is as ineradicable from the science and business of genomics as it is from any other supplemental writings on genomics, including this one.

The same can be said of other areas, such as IT or nano, where claims of revolutionary potential underwrite enthusiasm for scientific, commercial, and military investment. Moreover, as the dramatic collapse of the dot-com bubble points out, this rhetoric raises important questions of scientific, professional, and business ethics.

One of the features of revolutionary rhetoric is that it often suggests that technological developments alone drive social and economic change. But historians of technology, among others, have thoroughly exposed the problems with treating "technology" as the mainspring of social change, as if it somehow operated independent of human action. But exploring this rhetoric, and its limitations, is necessary to understand the speculative space of emerging technologies.

2. Scientific and technological practice

Of course, emerging technologies exist not only in a semiotic world of rhetoric and discourse; they are also material objects actively constructed in laboratories and their wider social networks. Fields such as biotech, IT, and nano depend on the people in them constantly developing new technical tools and knowledge. A new crop, a new database, a new nanoscale circuit is simultaneously the delivery on "revolutionary" promise and the outcome of the ordinary routines of laboratory and industrial activity. Studying the development of monoclonal antibodies, Canadian researchers Alberto Cambrosio and Peter Keating have demonstrated that technological "revolutions" take place not only through the development of new technical practices, but also through adjustments in a wide range of social institutions including marketing, the legal system, and the world of medicine.

Innovation doesn't stop in the laboratory, but continues as users take up the technologies, and sometimes modify or even reinvent them. Our Cornell colleagues Trevor Pinch and Ron Kline, for example, have shown how farmers and other rural dwellers adapted early automobiles designed to be passenger cars to country life, sometimes taking off the wheels and using them instead to run corn shellers and washing machines. While few people do this to their cars today, the same process of change and redefinition occurs when people

run programs on their top-of-the-line PCs to emulate clunky DOS programs that they prefer. Eric von Hippel has shown that users produce many of the innovations in the scientific instruments industry, as laboratory researchers tinker with off-the-shelf tools, reimagining their possibilities and engineering around their limitations.

The legal system provides yet another forum in which scientific and technical practice interact with other forms of knowledge through complex social rules, generating new meanings of technical knowledge that scientists consider stable, such as the re-framing of the DNA evidence in the O. J. Simpson case and the disputes over whether "innovation" in software requires Microsoft to embed browsers and media players within the operating system. Legal requirements for setting nonlethal doses or acceptable environmental releases lead to new studies – for example, on the toxicity of carbon nanotubes – and even to whole new areas of science, such as toxicogenomics, in which new technologies create opportunities to redefine cutting edge scientific practice, which in turn create needs for new technologies.

3. New institutional arrangements

Ongoing change in a variety of social institutions – the law, universities, capital markets, politics – is also an important characteristic of the speculative space of emerging technologies. Since the close of the 1970s, government policies intended to speed the commercial applications of science have increasingly turned knowledge into a commodity and produced big changes in research institutions. The emergence of biotechnology, for example, created what Berkeley anthropologist Paul Rabinow called "a new field of institutional arrangements and cultural practices." Seeking to link academic research to the private sector, governments have encouraged the creation of novel academic-industry alliances through tools such as the Bayh-Dole Act of 1980, new rules for intellectual property protection, technology transfer offices, and the development of new forms of what Sheila Slaughter and Larry Leslie call "academic capitalism." Of particular importance was the rise in the 1980s of startups founded by venture capitalists and university professors—many of whom kept their academic posts, as Martin Kenney has pointed out. Despite critiques warning that such developments would compromise the independence of academic scientists, these innovations proved irresistible, given competitive pressures and economic opportunities. In addition, national science policies are encouraging new kinds of multi-university and multidisciplinary collaboration, as exemplified in programs such as the National Nanotechnology Initiative. Emerging technologies now take shape not in traditional

academic or corporate settings, but in complex hybrids of public and private, university and industry, basic and applied.

The institutions involved in the development of emerging technologies go beyond universities and industries. They also include transnational organizations such as the World Health Organization and international regimes established by treaties on intellectual property, trade, and the environment. Non-governmental organizations (NGOs) also serve as key institutional players, both as funders of research (such as the Rockefeller Foundation's support of research on GM crops) and as critics of the structure and use of research (such as Greenpeace). Finally, military institutions are centrally involved in the creation of many new technologies.

Knowledge is reshaped as it travels, both metaphorically and physically, among these institutions. Issues of intellectual property and international diplomacy are deeply problematic for emerging technologies, for example, as WTO disputes about GM crops and pharmaceutical marketing suggest. The military poses particularly interesting questions about how hierarchical, bureaucratic institutions become enthusiastic champions of emerging technologies. In recent years, a "Revolution in Military Affairs" has highlighted the tension between a conservative institutional culture and the demands of international competition for military superiority, including the issues of dual-use posed by IT and other emerging technologies.

4. Politics of decisionmaking

The speculative space of emerging technologies poses difficult problems for political institutions, which are called on both to promote innovation and to protect the public from its undesirable consequences. Emerging technologies confront societies with a stream of potentially controversial issues: environmental clean-up vs. environmental catastrophe, information access vs. information privacy, biomedical wonder-devices vs. eugenics and the "yuck factor" of excessive human enhancement. The challenge of making policy decisions is compounded by ambiguity: How can government agencies develop appropriate regulations in situations where they expect "revolutionary" changes in technological capabilities that they cannot quantitatively model or perhaps even clearly imagine. In this context, producing credible expert advice, so critical to policymaking, poses especially difficult challenges. In regulatory situations, decision-makers face huge political risks (to say nothing of economic, social, and physical hazards)—as the collapse of confidence in the British state surrounding the BSE crisis illustrates. To overstate

the point, in the speculative space, decision-making capacity is weakest at precisely the points where it is most needed.

The "revolutionary potential" of emerging technologies compounds the problem further. To many observers, technologies such as cloning (e.g., somatic cell nuclear transfer), stem cell research, or GM crops seem to undermine the building blocks of society, basic ideas such as what counts as an "individual," a "human," or "natural." Similarly, many new developments in IT disrupt assumptions that are built into the routines of daily life. For example, the accumulation of databases on individual consumption – via grocery store records, credit card statements, and medical records – challenges beliefs about who controls information about our private activities. File-sharing services such as the original Napster and Kazaa and the open-source software movement that produced Linux are places where ideas about ownership and property are being redefined. In the speculative space of emerging technologies, policymakers find that what seemed to be bedrock beliefs sometimes become unstable or contested.

To compound matters, many issues involving emerging technologies are hashed out under the glare of media spotlights; yet others remain invisible to all but the tiniest circles of experts. Sometimes, though, a controversy arises and brings even the hidden issues into public view. Technological accidents such as the devastating 1984 chemical factory disaster in Bhopal, India, that killed thousands or the highly visible recent failure of the Columbia space shuttle can expose the hidden messiness of technological systems and the organizations responsible for managing them. Thus, it is no wonder that struggles to control the public display of information often develop. Worries about unanticipated consequences compete with worries about undue public alarm.

5. A new vision of emerging technologies

Each of the issues identified above plays a critical role in defining emerging technologies. But rather than thinking of emerging technologies simply as a cluster of challenges in rhetoric, technical practice, institutional arrangements, and politics, we need to recognize them as a coherent area for social concern. Looking at "emerging technologies" is different than looking at technologies that happen to be emerging. "Emerging technologies" is a peculiar speculative space in our social world, one that has concrete and far-reaching manifestations. Much work needs to be done to systematically map the contours, dynamics, and topology of the social, political, and technical features that constitute the speculative space of "emerging technologies."

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