8 Technological Change and the Challenges for 21st Century Governance

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The conventional wisdom on the accelerating rate of technological change is a truism, and might actually be truer than we realize.[1] In many respects, the changes to the fabric of daily life witnessed during the years from 1801 to 1900 were more fundamental than those occurring during the subsequent century from 1901 to 2000. But the 19th century's transformation was largely predicated upon political, social, and technological changes that had occurred during the preceding 18th century. While one must always be wary of historical analogy, the next 100 years may well witness a similarly breathless degree of change, this time based on the political, social, and, above all, technological changes that have taken place during the past 25 years.[2]

Continuous Change Becomes the New Constant

We are entering a world where the way people think and behave will be affected by discrete changes in emerging areas of technology as well as by the very dynamic of a continuous and accelerated process of change on all fronts. The phenomena of transformation, by their nature, deprive us of rules of thumb and past experience as guides. This is true for both the private life of the individual and the public life of the nation, thus exerting a powerful force on traditional structures and modes of governance. Key emerging technologies will, in themselves, present unprecedented challenges for governments to address. Another challenge is the constantly changing technological basis for all our society's interactions.

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In the broadest terms, the emerging technologies possessing the most prospect for transformation are: 1) electronic communications and computational ubiquity emerging from the information revolution; 2) human genetic and proteomic manipulation, biometrics, and bioinformatics; and, somewhat more prospectively, 3) developments in nanotechnology. This third area is the analog in the physical world to the small-systems approaches provided by the first two to the information sphere and biosphere respectively. Each technology has the common characteristic of potentially changing correlations of forces by leveraging the actions of relatively small groups of actors while providing a field for potentially important new entrants in the policy realm (corporations, nongovernmental organizations, etc.). Francis Fukuyama, Caroline S. Wagner, *et al.*, for example, further cite as the common hallmark of these fronts of technological change the challenge raised by each in supporting or even impelling a shift from collective control and hierarchical decision making to individual control and decision making.[3]

This suggests the existence of two broad currents among contemporary trends. The general one is the institutionalization of continuous innovation. Prodigious intellectual and economic resources are employed full-time to guarantee that tomorrow will not resemble today. More specifically, if the three areas discussed above achieve the prospects presently foreseen by their practitioners, the future transformation to the fabric of our public and private lives will be fundamental. The confluence of these trends, to the extent they continue and materialize into fact, will considerably strain the ability of governments and governance structures to guide the development of these technologies and address the outcomes ensuing from their development (or even perceive where the public's interest lies).

Emerging Technologies and Government Operations

The interactions between technology and governance are already complex. Government will ever more frequently be required to develop and act upon concepts for operations in areas increasingly defined by the new capabilities conferred by emerging technologies and the accelerated pace at which they appear. These technologies, in turn, will affect the nature of governance and, in some instances, the operational side of government.

For example, how can government take advantage of an increasing ability to outsource functions while not compromising the confidentiality of information? In other areas, fundamental issues of policy will be raised. For example, transformations brought by genetic manipulation and the biological revolution will probably provide the greatest challenge to the ability of government to understand and match the pace of change. This area will most directly affect traditional concepts of governance because of its substantial ethical implications.

It is clear that these emerging technologies and the implications ensuing from their development and application should be very much the concerns of those federal agencies with clear science and technology mission mandates. These agencies include the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), the National Institutes of Health (NIH), and coordinating and deliberative bodies such as the Office of Science and Technology Policy, the National Science and Technology Council, the National Science Board, and the President's Council of Advisors on Science and Technology. Just as we have seen the traditional "smokestack" industries begin to be transformed by the digital revolution (as embodied by the triad of microelectronics, telecommunications, and sensor technologies), so too we are beginning to see the more traditional governmental functions (such as those performed by the Departments of State and Justice, and certainly Congress) confronting the implications of emerging technology and ceaseless change. It is not so much a question of whether government will choose to avail itself of new capabilities made possible by emerging technologies, but how and how well. Indeed, emerging technologies will generate profound changes in the structure of governance itself.

Government and its operations must be a part of this sweeping change or risk its ability to function credibly. To what extent can we find ways for emerging technologies to enable government to fulfill its traditional role in this new environment—as well as those roles newly thrust upon it?

Addressing this question requires shifting the focus from technologies to the basic functions of governance. In broad measure, the legitimate purview for government operations in the American system has been to ensure the viability ("protect and defend") of national political and economic institutions. As a practical matter, meeting this goal requires:

- allocating funds to public purposes and then responsibly managing their expenditure;

- monitoring and regulating private activity in the interest of a commonly conceded public benefit; and

- either setting national agendas or providing the occasion for agenda-setting activities to occur.

This view, in turn, suggests a series of operational challenges to effective governance. Many of these challenges arise from technological change that may affect how well these principal government roles are performed. In particular, risks lie in the following areas:

1. We see a growing divergence between time cycles of government and those of technology development. Quite simply, this presents government operations with a Hobson's choice: Either live within a shorter response time and run the concomitant risk of ill-considered actions (or inactions) or see government input become less relevant and assume reduced stature.

2. The risk of insufficient access to information is large. This goes beyond the problem of gaining awareness of and collating relevant data series. A related and in many ways more problematic issue is that of managing and accounting for data and other knowledge resources. There is then, of course, the central task of analyzing and providing an interpretation of the data. These issues are already of concern and will increase in time.

3. Moving toward more operational issues, public sector actors must face the issue of identifying and mobilizing means for effective and appropriate action. For most issues, we have a choice among a series of alternative policy approaches. It will not be trivial in many cases to gauge which is most appropriate, given an environment defined by the scarcity of rules of thumb and previous experience to draw upon. Briefly, government measures may take the form of direct actions (e.g., deliberate choices for investment or subsidy and other agenda-setting actions), indirect actions (e.g., changes in taxation policy), the provision of auspices and venues (e.g., chairing meetings of potential user and producer entities at the pre-competitive stage of

technology development to discuss issues of standards, etc.), and activities related to active information gathering and dissemination.

4. Determining the appropriate sphere for government action is also likely to become a less clear-cut decision. Again, the potential ubiquity of outcomes ensuing from a variety of technology developments will multiply the number of direct stakeholders and interest communities as well as touch on matters of public interest. But beyond this, we might also consider that the government sphere is largely defined today by fundamental predicates of geography and biology. Both of these become more open to question as technological change creates virtual proximity and promotes alternative affinities on the one hand, and, on the other hand, carries the potential for altering fundamental assumptions about human nature, needs, and proclivities.[4] Deciding when government attention is warranted, the form such attention takes, and the timing of that attention will be increasingly tough calls to make.

5. The cross product of the first two points raises another issue of operational concern, namely how government bodies assess and measure performance in how well they have carried out their role. Agencies that fund research have already been grappling with how best to implement the provisions of the Government Performance and Results Act (GPRA). This is likely to grow as an issue for two reasons. One is the ubiquity of accelerated technology development and the implications for the mission portfolios of funding agencies that do not support science research and development (R&D). The second reason is because these agencies will desire to implement more managerial approaches to their daily activities, and assessment will be an important part of these approaches.

6. Worthy of explicit attention, but usually remaining only implicit in most considerations, is the issue that underlies so many of the forces bringing about the challenges listed above: the challenge of managing under uncertainty. This will be treated at length below.

What are the solutions that might address this list of growing challenges for governance? Some common themes of potentially desirable capabilities appear to run through this list. Each challenge suggests the need for access

to information and the ability to interpret and analyze that information. Beyond this, in each instance, we need procedures for utilizing such information to further public goals. Finally, and perhaps most challenging, we need tools for thinking through governance objectives and navigating toward them.

The balance of this chapter will offer a few suggestions for applying emerging technologies to government operations either to sustain those operations in a new environment or to confer new capabilities so institutions of governance can meet these new challenges. In each instance we face three alternatives. We could, either by volition or default, fail to avail ourselves of new technology-based means. Or we may choose to employ such means but only as an overlay on existing patterns and procedures of operations. A final course would be to re-engineer fundamental approaches in the light of new technology-based possibilities. Our general experience with new technology adoption is that only the latter course delivers full value.[5]

Tools for Information and Communication

As we have noted, many of the governance challenges raised by technological change in general and developments in disruptively revolutionary technologies in particular depend on accessing and communicating information. In the short term, we can consider several areas that can improve the operations of government in such circumstances.

Information Technologies that Better Utilize Data

It is (by now) a common view that our times are coming more and more to be characterized by the quantity of information being generated and shared. Timely access to quality information has become a prominent determinant of success in many fields for both individuals and organizations. We have a significant opportunity to enhance the value of government services by taking advantage of developments in the technology of information storage, access, search, and transfer. Doing this could significantly enhance the fiscal management operations of government as well as leverage and better coordinate government investment.

Many areas of traditional government operations could be transformed by applying information technology. For example, consider the area of information on science and technology. This example is apropos both for the subject of this discussion and because of the unique character of the federal R&D effort. One is hard pressed to name other vital federal government functions in the discretionary part of the budget that cross so many executive agency and congressional committee lines. It is hard to think of any parallel federal activity that has such importance and such broad involvement of so many agencies. And if this were not enough, the R&D planning problem needs not only to be funded, managed, and administered across the government, but also to be applied across quite disparate fields of science.

The demand has long existed for information that is more readily available, more integrated, and more usable on federal R&D efforts. In this and other areas, we need ways to support "smart" searches of bibliographic information by individual users; software systems that permit querying various databases and provide coordinated responses without needing to build a new, central database; and ways to parse information in a tiered system to meet the needs of users with varying requirements and levels of technological sophistication.

The RaDiUS ("Research and Development in the U.S.") system, maintained jointly by RAND and NSF, was intended as a tool to meet the need for viewing crosscuts of federal efforts in specific areas of research across agencies. But it might best be viewed as a model for similar systems that could be developed for other areas of governance. It combines an intelligent search engine and user interface with an ability to browse across databases maintained by different mission agencies, each with its own standards and format. It does this without imposing a uniformity that would have interfered with the functionality of those databases for the individual agencies.

The value of such tools in enhancing the operations of government agencies could be seen in several ways:

- enhancing the efficiency of information gathering and production;
- achieving synergy by combining different databases, and subsequently leveraging government information assets;

- increasing the timeliness of delivery;
- ensuring wider accessibility;
- multiplying contacts between individuals and authoritative experts, thus increasing the density of information-sharing networks; and
- increasing the ultimate effectiveness of information utilization.

Note that RaDiUS does not rely on special R&D data; it uses the operational databases of each agency. Similar systems could be created with the same technology to address other areas of government operations.

Such systems, enabled by emerging technology, should be recognized as advances in instrumentation. The history of science demonstrates the key role played by such technical advances in conferring an ability to draw new views of the world and its possibilities. The benefits that would accrue would certainly affect information flow between government and citizen, but would also profoundly affect information sharing and decision making within the government.

Improved Communications between Public and Private Sectors

Closely allied to the theme of information flow is the issue of e-communication between citizen and government. All agencies and Members of Congress have now embraced, to one degree or another, the use of e-media. But what about "retail" communications, in which one party initiates communication that contains specific information targeted to the other party (usually an individual)? Clearly, this is a large topic.[6] Many issues must be addressed relating to standards, costs and their allocation, security, the legal status of electronic communications, access across the "digital divide," technological barriers, and problems with social acceptance. Yet for government operations involving significant amounts of personal communication, e-mail (broadly defined) can lower costs, improve service, accelerate the "wiring" of the United States, and meet increased public demands for such options.

This prospect is certainly worthy of further exploration. To better understand the possibilities as well as the challenges, governments at all levels could begin to take preliminary steps. First, possible avenues for such personalized communications could be identified and catalogued. Some communications may be simply sending messages while others might address more complex actions. Some may be best facilitated by filling out fixed-field forms, while others might require more free-form formats. At the same time, facilities and standards for ensuring varying levels of security could be explored with the specific view of supporting the types of potential communications identified by agencies. A regulatory and legal framework similar to the one that applies to postal mail should be crafted for this medium as well. And most especially, we must begin now to consider the problem of access and inclusion for the "unwired." A system of national e-mail addresses might be considered that would integrate with the existing system of domain names but also provide at least the potential for access to all. Few steps currently available would more directly enhance both the perception and the fact of government responsiveness in a faster-paced world.

Internet-Based Public-Private Policy Forums

When it comes to agenda setting and regulatory activities, many aspects of government operations require interaction with the general public, stakeholders, and possessors of information and expertise. This will increasingly be the case as rapid technological development transforms all aspects of our society. A consistent message from several recent interview projects has been that a process that generates discussion, creates connections, and permits feedback would be of immense value in several realms.[7] Yet, the practicalities of engaging in such government-public panel discussions, even at the most general level, are a serious obstacle to utilizing these auspices. Opportunities are being missed because of the missing links in this chain of communications. The very exceptionality of such government-public discussions and forums has proven to be an obstacle to making such interactions more meaningful and organic to the structures now in place in both business and government. Expense and logistics are principal

barriers as well, hence deliberations remain relatively narrow and episodic rather than ongoing, and somewhat divorced from day-to-day processes in either business or government.

This presents another opportunity to link the trends of the computer and telecommunications revolutions to effect profound change at low cost, and to make a more drastic revision of the process than could have been contemplated previously. Web-based media can now support a wide variety of public-private panels in various areas of policy. We can conduct asynchronous, virtual panel discussions on a wide range of technical or policy issues. Several such panels could address different levels of concern. Web-based tools would not only permit discussion but also provide common access to widely available data sources and even to software tools embedded in the sites. These resources could be used to facilitate discussion and even permit these panels to be transformed from discussion groups to working groups. Such a tool, called a "hyperforum" (in the format first explored by researchers at the California Institute for Technology, RAND, and World Resources Institute) has been used several times in the course of project work and elsewhere.[8]

This vision encompasses not only wider participation but perhaps more meaningful participation as well. These Internet-mediated means would provide a flexibility that would obviate the need to drive too early to a possibly artificial and format-constrained consensus (as do, for example, standard Delphi approaches). The process could, instead, consider more widely the participants' alternative views of the further course and direction of a wide range of topic areas, especially those characterized by uncertainty and complex ranges of opinion. In addition, the reformulated process would reinforce the practical value of the ultimate product. During the course of such a hyperforum, lines of communication could be built or strengthened both vertically and horizontally, making implementation of any practical findings less burdensome.

Applying this emerging technology to supplement, or enhance, traditional government operations would fulfill several objectives by creating:

- a broader base of discussants, enhancing enfranchisement and "buy-in";

- more iterations and more time than a physical setting provides;

- support for both large-scale and one-on-one interactions;
- horizontal and vertical connectivity; and
- ultimately, more interactions leading to more cross-fertilization of ideas.

The technological reality of this vision could be quickly achieved, but the theoretical and social underpinnings would need more research. (In certain respects the technical means at our disposal have outpaced our understanding of how to apply them.) We would have to reexamine the cognitive psychological aspects of how groups function in order to translate this interaction to an entirely new medium. The initial use might not be as a fully functional framework but as a tool to augment other, more traditional, approaches for drawing in wider participation.

Despite teething problems for this new technology, the prospect places within reach a heretofore absent mechanism for sharing experience. It provides an avenue for evolving reflection by individuals and the larger group or groups, enabling users to examine side issues without running the risk of derailing the main effort, and placing the means to define and craft a collective vision at the disposal of participants. We can have an ongoing, meaningful engagement among people from government, industry, and universities. The technical means to transform the traditional conduct of government activity and apply this technology to the workplace would also elevate the quality of public policy discussion in many fields.

Navigating and Managing under Deep Uncertainty[9]

It is both an obvious and a subtle point: The principal challenge to governance in the midst of technological change is uncertainty. The biggest anxiety for conducting government operations is anticipating future conditions—and the awareness of the likelihood of surprise. Many of the operational challenges for government listed above revolve around the problem of how to conduct actions and craft policies that address a future that can

be only dimly perceived. As this condition becomes less the exception and more the rule, we need means for conducting government operations that explicitly recognize this uncertainty, rather than try to assume it away.

It is remarkable how infrequently the problem of managing under deep uncertainty is openly expressed.[10] Yet this uncertainty captures the most troubling aspect of governing in the presence of continuous technological change. This becomes even more the case when considering the implications of revolutionary and disruptive technologies for our political, social, and economic institutions.

Our lack of knowledge about future outcomes (or even technological pathways) is not a failure of due diligence on our part. Rather, it is the essential concomitant of the process of technological change. Many exercises worldwide in technology foresight, technology road mapping, and technology assessment either 1) fail to acknowledge this inherent uncertainty, or 2) are, at least tacitly, perceived by the participants and their government agency sponsors as being exercises in reducing uncertainty, or both. This, in turn, leads to an illusion of control that undercuts both the practice and the effectiveness of governance under these conditions.

A fundamental function of government is to draft and consider policy. A case can be made that a considerable amount of policy and operational decision making by government bodies is made under conditions of deep uncertainty where predictions are not possible. Different stakeholders will impute different future values to variables of central importance. ("What will be the budget surplus/deficit in FY 2007?" "Will the funding of Social Security and Medicare be adequate to the needs of 2021?" "What will be the extent of global warming in 2045—and how will this affect the global economy?" "What are the likely economic effects from the next 20 years of nanotechnology development?")

The standard practice is to generate forecasts, predictions, or other forms of best guesses to allow the policymaking and governance process to proceed. The technology for generating such analyses depends principally on scenario techniques, quantitative analysis and forecasting, and, more usually elsewhere than in the United States in recent years, Delphi approaches. Each has its own particular strengths and weaknesses.[11] All carry the common drawback of attempting to be predictive. Yet, both the generators of such information and its ultimate consumers would be astonished to see

the future actually unfold in the manner forecast. And none succeed in directly addressing the real needs of those charged with the tasks of governance.

In support of policymakers, the issue is not one of being better able to predict the future. This will not occur. Rather, the fundamental question is, "given that we cannot have reliable predictions of future outcomes, how do we conduct ourselves today in selecting the best option for action among the alternatives we have available?" We need new technology to support decision making under these conditions.

We have all become aware of the technical advances in computing technology encapsulated by "Moore's Law," which says that computing capacity doubles approximately every 18 months. (It is, of course, less a law and more a vision that has been more than amply fulfilled by the ingenuity of scientists and technicians in this field.) What is not as commonly understood are the possible implications of the resulting "ubiquitous computing" in which we are surrounded by an embarrassment of computing riches. In particular, this situation, already present in its earliest form, has implications for several aspects of government operations.

In the face of deep uncertainty, policymakers (and humans in general) wish to operate in an adaptive manner. That is, they craft plans through processes that are less deductive than inductive. They plan on knowing more tomorrow than they do today. And they conduct themselves in such a manner as to create options for taking later advantage of updated information. Further, they naturally gravitate toward solutions likely to be robust across a wide range of alternative plausible outcomes. That is, the tactic is often less one of maximizing behavior conditioned on a particular set of circumstances, than selecting among a set of "good enough" actions the one most likely to remain good enough across a wide range of plausible outcomes.

When decision makers turn to the analytical community, however, this is not the support they receive. Currently, the attempts to reason through such futures, determine options, and craft policies are supported by analytical tools developed in the days when computers were scarce, computing time dear, and memory virtually nonexistent. These techniques almost universally demand a single-point prediction and then develop some optimal "best-guess" solution around which strategy or policy is then crafted. (As a corollary, in most cases, people assume the existence of a unitary decision-

maker taking a once-and-for-all policy stance that will stay the course from today until the period being considered. This is not characteristic of our present political system and adhering to this concept for governance action would lead to increasing contradictions with the environment in which public bodies must act.) Thinking this way constrains policy choices, disenfranchises certain categories of knowledge and other information inputs, and leads to confrontational debates centered on arguments over which currently unknowable fact is most likely to prove true. In reality, searching for robust solutions (which naturally occurs as more and better information becomes available) takes place outside the framework of objective, fact-based analysis.[12]

In an environment of ubiquitous computing, however, new methods become available. We can move away from the model of using computers as glorified calculators, which are turned to only after humans have expended considerable effort in reasoning within the problem space. We can replace that with a model in which computers are integrated into the reasoning process. To do this we must create a system for designing, conducting, and drawing inferences from the outcomes of what may be called compound, computational experiments. Briefly, the insight is that when considerable uncertainty prevails, one can not be sure either of trusting a single model[13] as the best plausible representation of the underlying system or of having sufficient information available to use traditional quantitative analytical tools at the time when decisions must be made.

We need the ability to examine the full multidimensional landscape that is defined by the very uncertainties that span the problem space. Rather than examining one or a few structural or parametric alternatives, we need to conveniently and uniformly generate and examine many thousands of plausible specifications. Then we need to provide visualizations of the outcomes that are accessible even to those not skilled in quantitative analysis. Finally, we must enable the user to draw powerful insights in an interactive manner. The goal is to liberate users from the need to reason over singleton outcomes by enhancing their ability to reason over ensembles of outcomes, models, and scenario specifications. This possibility arises only as a result of the current speed and ubiquity of computing resources. The essence of the notion is to have computers do what they do best—generate

millions of calculations on an on-going basis—while humans then do what they do best—identify patterns, draw inferences, form insights, and interact with one another by drawing from a fuller range of visible information.

Such a system has been applied to several policy problems. The experience yielded an ability to draw strong conclusions in situations and for problems that had previously resisted standard analytical techniques.[14] This experience has particular relevance to the realm of public policy. It permits crafting a methodology that works backward from the ultimate question that requires illumination instead of using the traditional forward approach of first crafting the "best" model of the issue space. This, in turn, permits the user to look across the full landscape of plausible futures, examining candidates for actions and policies and testing them for robustness. The user can also test candidate strategies for failure and then assess how crafting policies designed from the onset to be adaptive might circumvent the weaknesses of the policy choices.

As a practical matter, several benefits for government operations ensue from such an approach. First, this approach permits the policy decision to be examined within the context of the problem to be solved so that the effect of different policy choices and alternative strategies can be examined across a wide range of plausible future scenarios. Second, crafting strategies that are explicitly designed to be flexible and adaptive permits the user to identify future signposts and decision points. Operating in this manner obviates the need to make predictions (when the best guess is likely to be quite wrong) in the chimerical quest for an optimal solution. Instead, it supports precisely the type of reasoning engaged in by humans when confronted with uncertainty: "Which actions appear to be most robust across the widest range of uncertainties?" "What current policies will lead to least regret while preserving options for the future when more will be known?" "What surprises may derail a chosen policy course and, once identified, what hedges, hybridization of policy instruments, or adaptive approaches may overcome the consequence of such surprise?" Finally, such an approach lends itself to the realities of the political process. It supports discussion among stakeholders by identifying—and validating—points of legitimate difference. It allows the sharing of visions and inferences among groups. And it may be utilized in a Web-deliverable format as the center of

a hyperforum type of Web-based discussion.[15] This is an example where an emerging technology may itself be used to enhance government ability to operate in an environment of accelerated technological change.

Rethinking Government Activity for Emerging Technology Fields

An environment of rapidly emerging technology may not only confer new capabilities on government operations but also modify the roles for appropriate government action. Results from several survey-based projects canvassing industry leaders have disclosed several areas where those in the private sector see an increasing void that could best be addressed by government operations.

Setting technical standards has emerged as an increasingly important issue affecting rates and directions of technological development in many industries as well as in basic research. Set standards too early and one runs the risk of stifling promising lines of inquiry; set them too late and rates of technical progress may be stymied by needless uncertainty. Among industrialized countries, the U.S. standards infrastructure is characterized uniquely by a loosely coordinated system of federal, state, and local governments, voluntary standards organizations, trade and professional organizations, for-profit entities, and semi permanent and *ad hoc* industry groups. Thus far, the U.S. system has effectively promoted both technological innovation and economic growth. But as the importance of technology grows in all industry sectors, shortcomings have appeared and questions have begun to arise. Failure to agree on standards for cellular telephony, for example, has been pointed to as a principal reason why European firms were able to capture both technological and market leads over their potential U.S. competitors.

In this environment, the role for government is not to set standards, but to convene and provide auspices for appropriate discussions to take place among producers, suppliers, customers, interested parties, and the government itself. (Industry people readily acknowledge the need to serve a public interest distinct from the private interests of the potential suppliers in a field.) Currently, practical and legal obstacles make it difficult for such discussions to occur in a timely fashion—if at all. Taking this on would be a

legitimate role for government and one that could be possible because of the capabilities conferred by emerging technologies that have been discussed above.

Similarly, the pace of technological transformation is disruptive of operations not only in government but also in industry. As even traditional "smokestack" industries become transformed through applying technologies of the digital and telecommunication revolutions, the technology factor as an element of the process that produces marketable goods and services assumes larger proportions. While a boon in many respects, such change also exacerbates the issues of complexity and uncertainty in business planning. Complexity and uncertainty are inherent concomitants of technology development. They are intensified by a growing need to become more fully aware of developments in other industries and other countries. The very rapidity of technological change makes issues of technology foresight nontrivial as traditional rule-of-thumb approaches based on past experience fail to apply.

Government operations already support limited efforts at technology assessment and foresight through the former National Critical Technologies Review process and government support of the World Technology Evaluation Center. Private sector feedback is that these are useful, difficult to reproduce as private efforts, and should be supported fully or even expanded.[16] To understand why, we should examine the value to individual firms. They rarely have the resources to do more than a cursory examination of their own industry in these areas. Further, they have limited access to truly unbiased sources of such information. They are not searching for definitive answers, but a baseline against which they can test their own perceptions and assessments. In addition, in the midst of so much technological change, there is value in framing a coherent vision of technology developments in the context of the higher-order goals we set for our society. Only government can fill this bill. Here again, the new capabilities enabled by emerging technologies can allow such a process to become integrated, seamless, and of considerable use both to the private sector and to public agencies (who would engage in discussions within a venue that would support such mutual explorations).

At the same time, as such a private-public partnership becomes more desirable and tractable, government agencies may relinquish some old roles or perform them in light of new options. As an example, the U.S. Depart-

ment of Defense and NASA have long been in the business of putting hardware into space and gathering data. As the leading edge of technology development passes from the public sector to the private, new options emerge. An early example is the Mission to Planet Earth program at NASA.[17] A portion of the data will be gathered from commercial sources rather than public ones. Integrated project teams of government and industry technical experts will define mission goals. Private science packages will fly on government platforms and vice versa. As the possibility for such interchange arises in other areas, government policy on issues related to data standards, data analysis funding, the purchase of data vs. the more traditional building of systems, and, of course, property rights will need to be confronted explicitly. This is an example of government operations conforming to a changing environment and the emergence of new opportunities and challenges. It is an instance less of directly applying emerging technology than of formulating policy for government operations in the context of emerging technology to make those operations more effective and thrifty.

Conclusion

I end with a note of caution. We face the possibility of falling into a subtle trap as emerging technologies translate into new capabilities that might be used in government operations. Many of these new developments are based on basic research that had been funded by various mission agencies. As this research has borne fruit in the form of new means for monitoring or responding actively, we see an understandable interest, indeed even pressure, for those agencies to begin to wield these new capacities and take on the provision of new or expanded service. (For example, the National Oceanic and Atmospheric Administration has an enhanced capacity for monitoring, understanding, predicting, and extrapolating consequences from changes in atmospheric and oceanic patterns.[18]) Through a now-familiar process, the existence of a technologically sophisticated ability we had not previously wielded quickly transforms into a perception that a mission agency and instrument of public policy *should* employ this ability to the general benefit. What was previously untenable now routinely becomes the expected.

These enhanced expectations for mission performance also generally require considerable outlays for a sophisticated infrastructure to support the new or expanded operational mission. As a general rule, budgetary allocations are not likely to keep pace with the costs of the more expensive operations. This pressures the traditional research funding activities that were the wellsprings of such new-found operational latitude. Such an agency now confronts the challenges of maintaining a standing force to support operations and doing so in a cost-effective manner), being in a position to respond to crisis, financing increasingly more expensive systems acquisition, and, at the same time, continuing the agency mission-supporting R&D.

One of the strongest findings from interview projects and the National Innovation Summit of 1999 was a near-uniform opinion that among the legitimate roles of government in an era of rapidly emerging technologies, one of the most important is to continue to support and maintain the system of basic research that made it all possible.[19] We need, however, to be sensitive to the possibility of unintentionally creating an ironic outcome when utilizing these technologies to enhance government operations: Utilizing these technologies should not come at the expense of placing at risk the sources of our future well-being.

Endnotes

1. This paper presents the personal views of the author and does not necessarily represent those of RAND, nor any of its sponsors.
2. This, of course, is a concept difficult to quantify and the statement itself is subject to multiple exceptions. But, in the main, the systems we have today and the technologies upon which they are based are recognizably similar to those in existence in the early 20th century while relatively few of those, in turn, bear a resemblance to their predecessors of the 1800s.
3. See *Information and Biological Revolutions: Global Governance Challenges*, Francis Fukuyama, Caroline S. Wagner, Richard Schum, and Danilo Pelletiere, RAND MR-1139-DARPA.
4. James Madison, noting that if we were all angels there would be no need for government, recognized the connection between governance structures and human biology and psychology.
5. This overview of technologically enabled means for affecting the challenges of governance draws solely from recent RAND work for illustration. Therefore, the specific references should be read only as exemplars of broader ideas and possible applications of emerging technologies and certainly not as fully representative of work along these

lines. Further, this chapter emphasizes those suggestions that might be actionable in the near term and that address only the aspects of government operations that are civilian and not concerned with national security.

6. *Sending Your Government a Message: E-mail Communications Between Citizens and Government*, C. Richard Neu, Robert H. Anderson, and Tora K. Bikson, RAND MR-1095-MF provides a far more detailed discussion.
7. *New Forces at Work: Industry Views Critical Technologies*, Steven W. Popper, Caroline S. Wagner, and Eric V. Larson, RAND MR-1008-OSTP, and *New Methods for Robust Science and Technology Planning*, Robert J. Lempert and James L. Bonomo, RAND DB-238-DARPA, discuss this in more detail.
8. Examples of this approach may be found on the Web at http://www.hf.caltech.edu /hf/b3/index.html
9. This section is a considerable abridgement of "Notes Toward a Robust, Adaptive Planning Methodology for Federal R&D," Steven W. Popper (2002), forthcoming.
10. Deep uncertainty describes the state where we do not know (and/or key parties to a relevant issue do not agree on) the system model, prior probabilities, and/or values to be used in an analysis.
11. Scenario methods tend to be narrative in character, consider only a limited set of archetypal scenarios/scenario families, and do not translate directly into actionable outcomes. Quantitative methods waste classes of available knowledge that are not easily quantifiable, illuminate only single points in uncertainty space, and require ex ante consensus before analyzing assumptions, models, and priors (in the Bayesian sense.) for the sake of analytic tractability. Delphi techniques are designed to drive to consensus through consulted expertise. But the history of technology both teaches the importance of having many guesses about the future (hence questioning the value of developing early consensus on the unknowable future) and raises questions about what expertise may be relevant, or even extant, to address the issues of concern.
12. Viewed this way, long-term federal budget processes are based on a string of single-point predictions of the future, which are believed by no one because neither the generators of such forecasts nor their consumers are foolish people.
13. Best viewed in this instance not as a map of reality but rather as a specification for calculation, that is, a computational experiment.
14. *Weapon Mix and Exploratory Analysis: A Case Study*, Arthur Brooks, Steve Bankes, and Bart Bennett, RAND DB-216/2-AF is an example. See also *Incorporating the Long-Term Future Into Analysis and Policy: Reasoning Through Visions of the Future Human Condition*, Robert J. Lempert, Steven W. Popper, and Steven C. Bankes (2002), forthcoming.
15. *New Methods for Robust Science and Technology Planning*, Robert J. Lempert and James L. Bonomo, RAND DB-238-DARPA provides an illustration.
16. See, as examples, *Global Science & Technology Information: A New Spin on Access*, Caroline S. Wagner and Allison Yezril, RAND MR-1079-NSF, and *New Forces at Work: Industry Views Critical Technologies*, Steven W. Popper, Caroline S. Wagner, and Eric V. Larson, RAND MR-1008-OSTP.

17. Discussed in *Data Policy Issues and Barriers to Using Commercial Resources for Mission to Planet Earth*, Scott Pace, Brant Sponberg, and Molly Mcauley, RAND DB-247-NASA/OSTP.
18. I am indebted to Dr. Bruce Don of RAND for calling this example to my attention.
19. *New Foundations for Growth: The U.S. Innovation System Today and Tomorrow,* Steven W. Popper and Caroline Wagner, RAND MR-1338.0-OSTP.