Yes, but not the one it already has.

Does America Need a Technology Policy?

by Lewis M. Branscomb

From semiconductors to supercomputers, jumbo jets to HDTV, technology is probably the single most important factor driving the evolution of global competition. The accelerating pace of technological innovation is spawning new businesses, transforming old ones, and redefining the rules of competitive success. Little wonder, then, that the national debate about the competitiveness of U.S. industry – and government's role in improving it – is increasingly becoming a debate about technology policy.

Usually, this debate centers on the question of whether government can or should play an active role in stimulating commercial technological innovation. Proponents of technology policy argue that a society's capacity for sustained technological innovation is crucial to its economic well-being. At a time when U.S. companies are steadily losing market share in strategic high-tech sectors, government support for R&D on "critical technologies" is absolutely essential.

Critics counter that however painful the loss of market share by U.S. companies might be, any governmental cure would be far worse than the disease. In a global economy where capital, technology, and people are mobile and where barriers to trade are falling, innovation itself is becoming global. Any effort by government to pick winners or otherwise unilaterally control technological outcomes within its own borders is certainly doomed.

> The issue isn't *whether* to have a technology policy; it's *what kind.*

Both these arguments have an element of truth, but neither captures what is really at stake in the debate over technology policy. The fact is, the issue isn't *whether* the United States should have a technology policy – it already does – but *what kind* of government policies and programs make sense in the new competitive environment.

Critics who attack the very notion of technology policy as some kind of dangerously radical new idea forget that the United States has had a technology policy since the end of World War II and spends more than $70 billion every year pursuing it. This policy takes the form primarily of government spending on defense-related R&D and on the development of military technologies.

Supporters of technology policy rightly argue that much of this money needs to be shifted from military to civilian applications. In the process, however, they often end up sharing the same mistaken assumption that shapes the very government programs they want to redirect. They take for granted that the chief purpose of government technology policy is to create new technologies.

But in a competitive environment characterized by nonstop innovation, simply creating new technologies – whether military or civilian – and funding basic research in universities are no longer good enough. Both are too far removed from the rapid pace of commercial innovation required to compete in today's high-tech markets. Think of consumer electronics, where Japanese competitors have triumphed by successfully commercial-

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izing technical innovations like the VCR invented in the United States. Increasingly, competitive success goes to those companies that can absorb and apply new innovations quickly–no matter where they have originated.

There is an important role for government technology policy in this process, but it is not the one that most supporters of technology policy think. Instead of concentrating on the "supply" of new technologies, government should stimulate "demand" for innovative ideas by helping companies across the industrial spectrum speed up the commercialization of good ideas to meet specific business needs. This can be done by encouraging collaborative research among companies and between industry, universities, and government labs; by investing in the technological infrastructure on which all innovation is based; and by helping develop the tools and techniques that all companies need to be more productive.

The books and reports reviewed here highlight the limitations of the technology policy debate and suggest the outlines of an emerging "demand side" national technology investment strategy. But mobilizing political support for this alternative will require a much more active interest in federal technology policies on the part of business executives–and not just those from high-tech sectors. Technology policy is too important to leave to policymakers.

On Technology and Competitiveness

Gaining New Ground: Technology Priorities for America's Future
Council on Competitiveness
Washington, D.C., March 1991.

The Technology Pork Barrel
by Linda R. Cohen and
Roger G. Noll
Washington, D.C.: The Brookings Institution, 1991.

Analyzing Japanese High Technologies: The Techno-paradigm Shift
by Fumio Kodama
London: Pinter Press, 1991.

Modernizing Manufacturing: New Policies to Build Industrial Extension Services
by Philip Shapira
Washington, D.C.: Economic Policy Institute, 1990.

Perspectives: Success Factors in Critical Technologies and **Perspectives on U.S. Technology Policy, Part II: Increasing Industry Involvement**
Computer Systems Policy Project
Washington, D.C., July 1990 and February 1991.

Decoding the Technology Policy Debate

The debate over technology policy doesn't take place in a vacuum. In fact, it is a response to the breakdown of the government's traditional approach to stimulating technological innovation.

For 40 years, an active federal government role in technology creation, diffusion, and adoption enjoyed a broad bipartisan consensus. During most of this postwar period, U.S. high-tech industry was largely unchallenged, and there was little need for debate about the technological roots of commercial competitiveness. This consensus engendered an implicit technology policy that decisively shaped patterns of technological innovation at U.S. companies.

This implicit technology policy consisted of two basic practices: generous government funding of basic research at universities and national laboratories and major investment by federal agencies in technology development directly related to their legally mandated missions. Policymakers assumed that government-funded science would benefit private industry by feeding a pipeline of innovation eventually leading to new technologies and whole new industries. And government-funded technology development, they reasoned, would spin off useful technology to the commercial sector.

Many government agencies participated in this "supply side" strategy. But because of the Cold War, the Department of Defense dominated it. In 1960, U.S. defense-related R&D comprised a full third of *all* public and private R&D in the industrial nations making up the Organization of Economic Cooperation and Development (OECD). Today defense R&D still constitutes 31% of total U.S. R&D expenditures. The government's network of national laboratories, for example, is still largely dedicated to military and space research.

This system worked reasonably well for more than 30 years. Military R&D and procurement were critical in the early development of the electronics, computer, and aerospace industries. And while the diffusion of military technology to commercial companies was often slow, it didn't make much difference since no foreign companies were seriously challenging the U.S. lead in these markets. During the past decade, however, all this has changed. Those changes have rendered obsolete the assumptions that drive the implicit U.S. technology policy.

The pipeline model of innovation depends on fundamental breakthroughs in basic research to spawn new kinds of products and new industries. But increasingly, competitiveness depends less on seeding fundamental breakthroughs than on combining low-cost manufacturing with high-quality products. Keeping a product line competitive requires continuous, incremental improvements in function, cost, and quality. In such an environment, no amount of basic research can make a manufacturing company competitive. Cost-sensitive design, new process technologies, manufacturing systems engineering, and the like are far more important.

This is where Japanese manufacturers have excelled. According to one study, Japanese companies invest roughly 70% of their R&D in process technology, whereas comparable U.S. companies invest about the same proportion in product R&D. Also, Japanese consumer electronics companies often introduce a new technology in a low-end consumer product rather than at the high end of the product line. This gives the company early experience at manufacturing the technology at low cost; the cost advantages multiply when the technology is later introduced in high-end products.

So too with traditional assumptions about "spin-off." The government's implicit technology policy assumed that spin-off was both automatic (meaning the government didn't have to make much of an effort to facilitate commercial access) and free (because the government's costs were justified entirely by the missions of its agencies). But the unaided and unplanned diffusion of defense technology to commercial companies is simply too slow, too inefficient, and too narrowly restricted to a few defense-related industries to constitute an effective strategy for competitiveness.

Proponents of a more explicit technology policy try to address this situation by calling for a major shift of funding from military to civilian projects. The artifact of this approach is the "critical technologies" list, which purports to describe those technologies crucial to future economic well-being and to serve as a guide for government investment. Under pressure from Congress, the Department of Defense published the first such list in 1989. Not to be outdone by Defense, the Commerce Department published its own list in 1990. Further prodding from Congress led the White House's Office of Science and Technology Policy to follow suit in 1991. Now both Japan's Ministry of International Trade and Industry and the European Community have their lists as well.

"Gaining New Ground," the recent report of the Council on Competitiveness, is the first effort of a business organization to come up with a critical technologies list. The council is a private business-led organization formed by Hewlett-Packard's John Young and other business leaders. Its report provides a detailed evaluation of U.S. companies' strengths and weaknesses relative to foreign competitors in 23 critical technologies. The council urges business and government to develop "coherent policies to ensure U.S. leadership in the development, use, and commercialization of technology."

> "Critical technologies" lists exemplify what's wrong with the technology policy debate.

Ironically, this profusion of lists exemplifies what's wrong with how the debate about technology policy is framed. Even the most casual reader soon realizes that all these lists are essentially similar. The same technologies–microelectronics, biotech, software, and computers–keep appearing over and over again. In general, these are areas where the private sector has already invested heavily and where the ratio of privately financed R&D to sales is high. So it's not clear what, if anything, the government should do about them, short of contributing even more money than it already does. Indeed, it might make more sense for government and business to identify technologies *not* on the usual lists, so as to invest in areas of expertise that would distinguish U.S. companies from competitors.

Critics, persuaded that investment decisions will inevitably be based on political rather than economic or market criteria, resist such targeting. Ample evidence for their concern can be found in *The Technology Pork Barrel* by Linda R. Cohen and Roger G. Noll. The authors examine a number of large-scale federal R&D commercialization projects of the past 20 years. They conclude that in many cases, reasonable economic and performance goals were cast aside once political and financial commitments had been made. Even when the initial business case for a new government program is attractive, argue Cohen and Noll, the public money such programs receive ends up creating its own constituency. The program is soon corrupted into yet another "technology pork barrel," transcending ideology and partisan politics.

Both Jimmy Carter and Ronald Reagan, for example, supported the Clinch River breeder reactor, experimental nuclear power technology designed to create more fuel than it consumed. Funding, which totaled $5 billion between 1969 and 1983, continued for five years after the project had become obviously uneconomic. The Nixon administration continued with the U.S. supersonic transport long after its costs ballooned and the estimated number of passengers it could carry had begun to shrink. Synthetic fuels projects, initiated in the quest for energy independence, never enjoyed competitive economics. Of all the projects Cohen and Noll study, only one has led to a new commercial technology – the solar photovoltaic program to generate electricity directly from sunlight. However, the technology is still confined to small niche markets, and it's not clear how much the government's investment accelerated the progress that might have occurred anyway.

Cohen and Noll demonstrate the near impossibility of managing both the politics and the economics of large-scale commercialization projects. But of course that is not the only way to frame a technology policy, as Cohen and Noll themselves recognize. There is another way to think about government's role in encouraging commercial technology development – one that does not take on the expensive task of commercializing all the elements of a given technology but instead concentrates on improving the ability of companies to adopt and adapt technologies that either already exist or that represent an important new competitive opportunity. In order to understand why such an alternative makes far more sense given the new realities of global competition, consider the case of Japan.

Competing by Technology Fusion

Just as Japanese manufacturers have pioneered many of the changes in manufacturing techniques described above, they may also have the clearest understanding of the new model of industrial innovation that follows from these changes. Take, for example, the recent book *Analyzing Japanese High Technologies: The Techno-paradigm Shift* by Fumio Kodama, former research director of Japan's National Institute for Science and Technology Policy. The Japanese edition of Kodama's book won the 1991 Sakuzo Yoshino prize for the best book in the social sciences published in Japan, the first time an engineer has ever received the award.

According to Kodama, the traditional "breakthrough" model of innovation is being replaced by a more dynamic system that he calls "technology fusion" – the combination of already existing technologies or engineering and science disciplines in new hybrids that are greater than the sum of their parts. The fusion of electronic and optical technologies, for example, gives birth to "opto-electronics," allowing a company like Sharp to be a major player in technologies ranging from color televisions to liquid crystal displays to customized integrated circuits. The combination of electronic and mechanical technologies spawns "mechatronics," making Fanuc, a Fujitsu spin-off that makes computer controls for machine tools and industrial robots, one of the most profitable companies in Japan.

> Companies must learn to absorb new technologies, "like waves crashing onto the beach."

Because of the dynamics of technology fusion, established technologies in any industry constantly run the risk of being displaced by radically different technologies coming from outside. As a result, traditional distinctions between high-tech and low-tech industries are fast disappearing. In effect, every business is, or should be, high tech. And the critical resource for competitive manufacturing is not so much capital and labor but R&D. Looking at the total of all Japanese manufacturing companies, Kodama finds that the ratio of annual R&D to capital expenditures is 1.26:1 and growing. The bottom line: manufacturing companies are increasingly R&D driven.

But it is not your typical R&D. Successful companies are not necessarily those that *create* new technologies but those that rapidly *absorb* them – in Kodama's words, "like waves crashing onto the beach." This requires an organizational capacity to spot promising new technologies worldwide and quickly incorporate them into new products and processes.

To do so effectively, companies have to be good at what Kodama calls "demand articulation" – fashioning a technology investment strategy with a well-defined vision of the business applications a company wants to make happen. This organizational capacity – rather than specific features of any technology itself – determines how quickly new technologies are diffused within a company.

Kodama suggests that a company's capacity to absorb and adapt technology is increasingly becoming the key to business strategy. As mature markets become saturated, Japanese companies are using their ability to apply new technologies to specific business needs to shift into new and more profitable markets. Canon has moved from cameras into office equipment such as laser printers and facsimile machines. NEC has moved beyond its original base in public telecommunications switching and transmission equipment to mainframe computers, semiconductors, and, most recently, mobile telephones and laptop computers.

The new dynamics of industrial innovation that Kodama describes put a premium on the ability of companies to borrow new technologies from all over the world and put them to the service of innovative business applications. Helping companies develop that organizational capability is an important new mission for government technology policy.

Building an Alternative Technology Policy

What might a "capability enhancing" technology policy look like? Instead of focusing on picking winners, it would engage in activities that improve the overall innovative capacity of companies and the nation.

The closest the current debate comes to identifying such activities is in two other bits of policy jargon: "precompetitive" research on "generic" technologies. Let's consider each term in turn.

The commonsense definition of "precompetitive" is any kind of R&D that isn't proprietary. A more precise adjective would be "not anticompetitive." As a guide to policy, this is unacceptably broad. But it does suggest one appropriate role for government: to support R&D that underpins a broad array of specific technology applications in many different industries, while stopping short of supporting proprietary technology that companies themselves should fund.

There are ways to encourage precompetitive R&D that do not involve spending public money. A big step would be to dismantle some of the many legal barriers blocking collaboration among companies and between companies, universities, and government labs. For example, in the 1980s, Congress exempted companies that participate in research consortia from liability in civil antitrust suits. This has contributed to a variety of initiatives. Examples include the Microelectronics and Computer Technology Corporation, a consortium of 15 U.S. computer companies engaged in research on electronic packaging, software development tools, and massively parallel computer architecture; and the Open Software Foundation, a collaboration of computer manufacturers and software companies to develop standard interfaces so that customers can easily link together foundation members' products.

> One new area for government support is "generic technologies" that make all industrial innovation possible.

The concept of "generic" technologies is even more useful. Think of such technologies as making up the technological infrastructure that makes all industrial innovation possible. Advanced computer-aided design tools, for example, can improve productivity throughout U.S. manufacturing. Measuring and control instruments are essential for improving quality through careful process control. New fabrication processes can increase both productivity and quality. And better technical data can spur innovation. For instance, new techniques for materials characterization can provide a quantitative basis for predicting the performance of advanced materials.

Such technologies are rarely glamorous enough to attract substantial political support. They are frequently ignored in favor of more exciting basic research on one side and more politically attractive technology demonstration projects on the other. Still, they can be of great value to all companies and do not unfairly benefit or penalize any particular sector or industry. By increasing the technical productivity of a company, these generic technologies can help accelerate commercialization and support aggressive efforts to cut costs and raise quality. In this sense, they can be seen as creating demand for innovations and new technologies.

In a recent example of government support for a crucial generic technology, Congress authorized funding last November to upgrade Internet, the collection of more than 2,000 computer networks linking universities and research labs around the country and to the rest of the world. The goal is to create a National Research and Education Network (NREN) that will expand Internet to serve schools, universities, government, and industry. NREN is important because it will greatly increase the capacity for collaboration by many geographically dispersed companies and institutions. It will also help create a national market for improved information services, which in turn can enable companies to accelerate the commercialization of new technology.

Another government-supported activity that could have an important commercial payoff is technical assistance to companies to improve their ability to use new process technologies such as computer-aided design, computer-controlled machine tools, or electronic data interchange. Such programs often go by the term "industrial extension" – an analogy to the federal government's elaborate and highly successful agricultural extension service that began early this century to provide technical assistance to the nation's farms.

Modernizing Manufacturing by Georgia Institute of Technology researcher Philip Shapira is the best guide to the industrial extension concept. When it comes to manufacturing, Shapira argues, technology assistance in the United States is far more fragmented and less developed than in other major industrial nations including Japan. For example, in 1989 the federal government spent roughly $63 billion on R&D; only $500 million – a mere 0.8% – went to encouraging technology transfer.

In recent years, however, a number of states including Massachusetts, Michigan, New York, Ohio, and Pennsylvania have organized industrial extension programs of their own, often in collaboration with local universities. Some new federal programs also move in the same direction. For example, since 1988, the Commerce Department's National Institute for Standards and Technology has established six regional Manufacturing Technology Centers to work with small and midsize manufacturers to improve their productivity.

Focusing on demand-side policies such as precompetitive research, generic technologies, and industrial extension does not mean that the government should foreswear more traditional supply-side support for commercially relevant R&D. But to protect against the politicization that many fear will overtake any such effort, the criteria for promising projects need to be far more precise than those implicit in the typical critical technologies list.

There is a strong case for public support of high-risk but potentially path-breaking technologies such as high-temperature superconductors. The best model for government's role is the Defense Advanced Research Projects Agency (DARPA). DARPA has a formidable record at making strategic investments in cutting-edge technologies that eventually lead to commercial benefits. Its small staff is unbureaucratic, highly professional, and technically competent. And the agency's mission – to explore high-risk technologies of potential military importance – also insulates it from political pressures. One way to further leverage DARPA's contribution would be to expand the agency's mission to include dual-use technologies of value to both the military and the commercial sector and to strengthen the agency's ties to commercial industry.

Finally, the government should support strategic technologies to sustain industries deemed critical to the national interest only in very special situations. It's not enough just to show that the industry is vital to the nation. There also has to be a practical strategy for turning it around – and a demonstration that companies have signed on to the effort.

The real problem with Sematech is that it does not go far enough.

The closest existing example of this kind of activity is Sematech, the controversial consortium of large U.S. semiconductor manufacturers. Created to ensure that U.S. semiconductor equipment manufacturers can keep pace with the accelerating technical demands for rapid miniaturization, the consortium is funded by matching grants of $100 million each from private-industry members and the federal government.

Sematech supporters argue that the survival of the U.S. semiconductor industry in the face of Japanese competition is a matter of urgent national concern and, therefore, that the government should share in the project's costs. Meanwhile, critics have attacked the government's role in Sematech on the grounds that if the initiative is crucial to the future of the semiconductor industry, the industry should fund it on its own.

The real problem is that Sematech does not go far enough. The consortium has been successful in increasing collaboration among semiconductor manufacturers and their suppliers in the equipment industry. But if the survival of the U.S. semiconductor industry truly is at stake, then improving the technology of equipment manufacturers will by itself do little to revive it. Indeed, to the degree this focuses the industry and government on a narrow, technical quick fix, it may actually be an obstacle to developing a realistic technology policy for the sector. A policy that would take seriously the challenges facing the U.S. semiconductor industry will have to address not only technological factors but also issues of capital investment, market structure, industry structure, and trade policy.

For any of the above policies to be effective, managers need to find ways to make their voices more clearly heard in shaping and implementing technology policy. Even as the debate over technology policy heats up, there has been a trend toward the politicization of government funding for basic research, with more and more congressional appropriations going directly to academic institutions without first undergoing competitive evaluation. Unless the business community takes a strong hand in how policies are set and how the competition for funding is managed, the result could be a pork barrel of embarrassing proportions.

One example of how industry leaders can organize to express their views is the Computer Systems Policy Project (CSPP). CSPP is an affilia-

CSPP illustrates a business-led, demand-oriented approach to technology policy.

tion of 12 major U.S. computer systems companies, including Apple, AT&T, Digital Equipment Corporation, IBM, and Sun Microsystems. Through CSPP, the CEOs and chief technical officers of member companies meet with government officials to encourage a more informed understanding of the competitive dynamics in their industry and to identify areas for public-private partnership.

In its reports, CSPP has called for the modernization of science and engineering education and for infrastructure investments in the nation's computer networks. Recently, for example, CSPP proposed a major expansion of the government's long-term plan to renovate the nation's computer networks. The organization argued that research on critical technologies should be tied to efforts at solving key business and social problems – for example, better health care and medical services, enhanced industrial design and intelligent manufacturing, and broad public access to public and private databases. This is precisely the kind of business-led, demand-oriented approach to technology policy the United States needs.

Of course, much of the demand-side technology policy remains to be translated into action. And there is much room for different views on the government's capabilities and on industry's needs. But surely proponents of technology policy and its critics can both agree on the good sense of helping companies – and society as a whole – prepare for a global economy where the rapid absorption and application of innovative ideas is the linchpin of competitive success.

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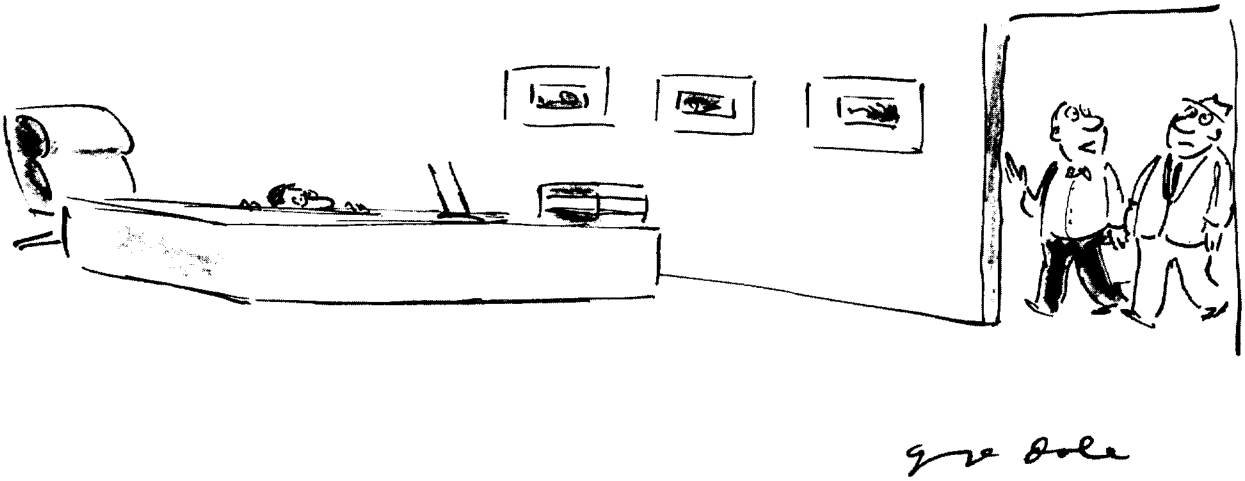

"Bemis likes to keep a low profile."

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