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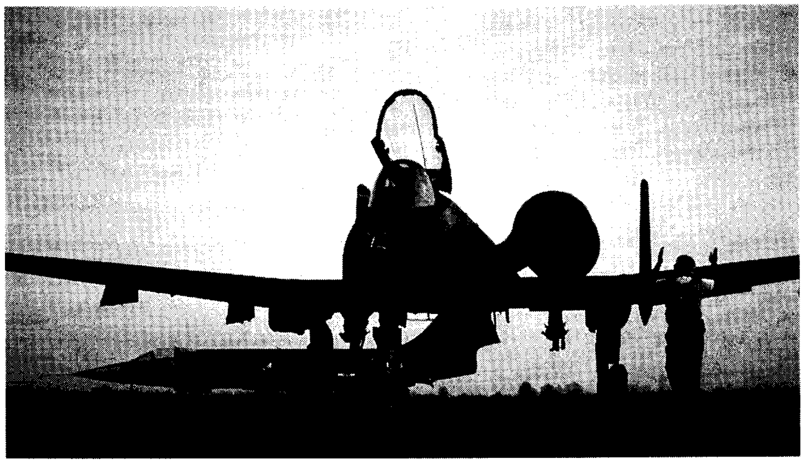

U.S. DOD

Technology and public policy are inherently interdependent in industrial societies. In the United States technology policy in the defense area has led to many spin-offs into commercial products.

Do We Need a Technology Policy?

The current debate on United States technology policy is driven by the same factors that launched the debate on U.S. industrial policy in the 1970s: the nation's trade balance remains negative; productivity growth is slower than in many competitor nations; and U.S. firms continue to lose market share in many product sectors. These trends are occurring even though the United States remains the world leader in fundamental research. This growing disjuncture between the nation's position in research and its position in commercial technology suggests that a reexamination of the government's role in the commercial area is overdue.

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This reexamination requires clarity concerning the meaning of "technology" and "technology policy." Technology as we use it denotes systems created by humans to carry out tasks they could not otherwise accomplish. Examples include the creation and use of airplanes, computers, telephones, and pharmaceuticals by complex sociotechnical systems, that is organizational systems composed of tightly coupled hardware and social parts. Technology policy comprises actions by government aimed at assisting or stimulating delivery of competitive goods or services by sociotechnical systems.

We seek to contribute to the reexamination of policy by identifying and defining the essential functions of a technology policy. For this purpose it is important to emphasize that an effective government role involves assistance and stimulation but not doing. We have been unable to identify any case in which government run (as opposed to owned) industries have been able to carry out technology development over an extended period of time effectively enough to meet commercial competition. At the same time government assistance, or resistance, often makes the difference between success and failure in the increasingly globalized marketplace.

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U.S. Policy

The U.S. has long had self-conscious technology policies in defense, medicine, and agriculture. The present debate is occurring because many observers see now a need to develop similar policies for commercial technologies [1], [2]. Advocates of a self-conscious U.S. commercial technology policy believe that: 1) internationally competitive technologies are essential if the nation is to maintain its standard of living; and 2) government support and stimulation is important to maintaining competitive industries.

U.S. development of policy which supports commercial technologies has been seriously inhibited by two conceptual problems. The first flows from an American ideology which celebrates the virtues of free markets, and thus suggests any government involvement in the market is inherently imprudent. The core theme of this ideology is that capitalist societies must be *laissez-faire* in structure and operation [3]. This powerful value position places the burden of proof on those advocating government support of commercial technology.

The second conceptual problem results from lack of any predictive theory that can provide guidance on which government actions would be effective in supporting innovations and competitive technologies [4]. Theory in this context includes numerical models run in computers. The lack of adequate predictive theory is exemplified by the extraordinary variety of approaches taken to technology policy by the OECD (industrially developed) nations and various states in the U.S. [5], [6].

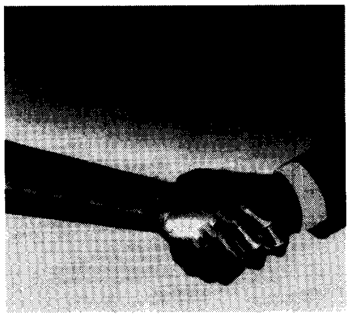
Both conceptual problems are exacerbated by continuing efforts to use inadequate economic theory. Most of this theory assumes the neoclassical model of a free market with buyers and sellers who are rational economic actors making decisions on the basis of three static variables: labor, capital, and resources. As Porter documents, these static variables are grossly inadequate for understanding competitiveness [7]. In the U.S. policy-making context, this inadequate theory has caused confusion in two ways. First, it gave support to the value based *laissez-faire* ideology. Second, it supplied a purported explanatory and predictive model of real world economic behavior which leads to simplistic conclusions. Never mind that the limits of this neoclassical economic theory have been the focus of sufficient volumes to fill whole sections of libraries; its impact on the technology policy debate remains powerful [3], [7], [8].

We will not add to the debate concerning the adequacy or inadequacy of this economic model. Rather, we assert that quantitative estimates of the complexity of the sociotechnical systems with which technology policy must deal place those systems well beyond the reach of any economic or other type of current, or foreseeable, predictive theory [4]. In the absence of predictive theory where does one go for guidance on the key factors technology policy must address? We see no alternative to careful empiricism, that is, looking at what has happened in the past over a wide range of experiences and summarizing the lessons those experiences teach us. This summary is the next task.

Lessons from Experience

First, whether by direction or indirection, advanced nations have had technology policies since at least the middle of the last century because technology and public policy are inherently interdependent in industrial societies. In the United States, these links have been manifest over history via many kinds of government actions, for example: patent policy; the land grant acts for railroads; the creation of the land grant universities via the Morrill Act; the protection of the steel industry via tariffs; and in more recent times many spin-offs from defense technologies into commercial products, and a broad support program for medical technologies. Indeed, there are so many actions of this type that it is hard to count all the agencies and all the types of public policy decisions which have affected technological enterprises in the past. The question facing the United States is not whether to have a technology policy, but rather whether the policy will be formulated openly and directly or in an *ad hoc* and indirect way via Congressional and agency decisions whose primary purpose is other than fostering competitive technologies.

Second, there is no meaningful way to differentiate among high technology, other technology, and related services, which is useful in regard to fostering competitiveness. However defined, high technology is continuously changing; what is high technology today may not be high tech tomorrow. What was called high technology in the semiconductor industry has totally changed several times in the past two decades. The revolutionary "lean production" methods pioneered at Toyota Motors between 1950 and 1970 have become the centerpiece of competitivieness during the 1980s for manufactured articles with a high piece count, thus outmoding what for decades had been the most advanced methods of manufacture. Lean production involves "inskilling" rather than "deskilling" workers, and thus leads to far more rapid innovations of both processes and products. The formation of well integrated networks of small companies, as in the Italian shoe and fabric industries, leads to the same speed-up of changes in competitive practices [7], [9]-[11]. Both systems allow easier and more rapid integration of new materials components and subsystems into nominally mature technologies. In the auto industry, for example, we may one day find competitors producing bodies of composite materials, and engines made of ceramics which reduce costs and improve reliability. Since the automotive industry (in a broad sense) accounts for roughly 1/6th of the U.S. economy, technology policy cannot be restricted to a set of "critical technologies," nor can it be successfully operated by a set of general guidelines or decision rules [1], [12].



Third, the critical characteristic of contemporary technology as it impacts competitiveness is continuous innovation. Some find it useful to divide innovations into three time scales: 0-2 years, 2-10 years, and more than 10 years, in order to emphasize that continuous efforts need to include not only incremental and radical innovations but also long-range fundamental research [13]. We live in a world in which continuous improvements in quality, performance, and production efficiencies are the norm; firms which stand still will, in the not very distant future, fall behind. To put this differently, more and more sectors of the international marketplace are becoming structured around innovation-to-obsolescence cycles in products, processes, and services. In such sectors, any specific technology policy will become obsolete, sometimes in no more than a few years. Technology policy must therefore be concerned with structuring a flexible policy-making system which is quick to sense and respond to changes.

Fourth, commercial success is normally enhanced if both process and product are considered as matters for innovations. This lesson is particularly important for the U.S. because many of the recent successes of foreign competitors appear to have resulted from a heavier emphasis on process innovations.

Fifth, the sources of and the routes to innovations differ among industrial sectors. In many sectors, small cumulative innovations are critical to commercial success; this is particularly true in relatively mature industries such as consumer electronics and automobiles. In these sectors, innovations often depend more on inputs from design, development, production, and marketing than from research, especially fundamental research. In other sectors, such as pharmaceuticals and chemicals, success rests much more directly on radical innovations and long-range research. In these sectors, a tight link between R&D, production, and marketing often becomes very important.

Sixth, the sociotechnical systems which create goods and services in the late 20th century frequently take the form of networks or webs which transcend single companies and national boundaries [14]. These networks are fluid in action and minimally hierarchical; this makes it possible to synthesize the expertise and skills necessary to accomplish a wide variety of innovations. The networks serve a number of needs; the most critical is effective flow of information and knowledge. Thus technology policy must be self-conscious about the need to foster network building in order to maintain competitiveness in many situations. In other words, technology policy must recognize the need for cooperation and coordination among activities in government, industry, universities, and nonprofit institutions and aid in removing barriers to their interaction.

With this empirically based appreciation of the general circumstances and processes needed for effective innovation and competitiveness, we now turn to an identification and discussion of the functions which technology policy needs to carry out. Our focus on the basic functions of technology policy reflects two perceptions: 1) moving to specific proposals before there is good understanding of the necessary functions can be dysfunctional; and 2) the basic functions have not been adequately clarified in past U.S. debates concerning technology policy.

Four Functions of Technology Policy

If, as suggested above, successful technologies require interdependent efforts by government, industry, university, and nonprofit institutions, then what are the key functions which government needs to carry out? We suggest four: 1) climate setting; 2) surveying; 3) coordinating; and 4) gap filling.

▼ *Climate Setting*

Technology is both embedded in and impacts most aspects of industrial societies. As a result, many areas of public policy impact technology. If the general body of public policy does not create a hospitable climate for technological enterprises and innovations, then the larger and more successful enterprises are likely to seek other homes, and there is little that a specific technology policy can do to maintain competitiveness. A large diversity of elements make up a hospitable (or less than hospitable) climate. A primary element of the climate is clear identification and wide acceptance of the idea that commercially competitive technologies are necessary to a high standard of living and, therefore, technological innovation constitutes a national need of high priority. To

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gain this wide acceptance, national leaders need to communicate this priority repeatedly by word and deed.

The diversity of what climate setting entails can be understood by considering the role of policy in the creation of a hospitable climate for each of the three components of a hardware producing-using system: inputs such as labor and capital; organizational systems; and the international marketplace.

An important input is "patient" (long-term investment) capital. Thus the extent to which governments make such capital available is an important climate-setting factor. Many comparisons of the current situation of the U.S. with that of Japan show not only that the Japanese enjoy great advantages in the area of capital but also that this advantage is in large measure the result of conscious government policy. The range of government actions which affect the capital climate include: taxes; depreciation schedules; regulations concerning securities and corporate behaviors; government procurement processes; budget deficits through their effect on interest rates and availability of credit; and many others.

A second critical input is people with many kinds of skills ranging from research to production and marketing. Public education provides the substructure on which the creation of many of the necessary skills can be built. Beyond public education, the government plays a role through forecasts of personnel shortages in key areas, in the regulations which support or deter the retraining necessary because of innovations in products and processes, and in social support of the workforce through such programs as medical insurance and tax laws regarding retirement set asides.

Americans, during most of the period since World War II, have subscribed to the view that most of the ideas supporting innovations came from scientific research. Support for long-range research was seen, therefore, as the primary role of government in supporting technological competitiveness. It is now widely recognized that in many sectors innovation is heavily originated from ideas arising in marketing, production and design processes [15]-[21]. The belief that research was the source of innovation, led to federal support of fellowships for graduate students in the sciences and in engineering research areas which deemphasized the critical manufacturing sector. This support gradually shifted the focus of engineering faculties away from design and production toward research. By the 1980s, this created a significant imbalance within the engineering education system [22].

The point is, federal policies have and do affect everything from where both public and private R&D monies are spent to the nature of engineering education, to financial incentives for (or against) patient capital, to job security (or insecurity), to the nature of the social support system, to the potential for capturing profits from patented devices, and to other matters. None of these government actions alone constitutes a controlling element of climate; taken together, they determine a major part of the climate for innovations crucial to competitiveness.

A hospitable climate for innovative organizational systems is one which provides for both stability and flexibility. For organizations or networks to compete in markets structured by innovation to obsolescence cycles, the organizational systems must focus on the long as well as the short term. Inasmuch as innovations frequently require new mixes of skills, retraining of personnel, and the capacity to acquire new skills must be facilitated. Fear of job loss, mergers and takeovers, and demands for short-term returns on investments create environments which are not conducive to innovations. All these matters are affected by government actions which deal with fiscal policy, labor unions, health care, limits to liability, tax regulations regarding retraining of workers, plus many others. Here again, many actions by government contribute to the climate for technological innovation.

The last component of climate setting concerns the market. In many sectors, the market is increasingly international. Over time, an increasing number of nations made a trade surplus a high priority national goal. Many instruments can be used in pursuit of this goal, such as surveying of opportunities by diplomats, financing of purchases of foreign companies to acquire advanced technology, and trade barriers of many types. In the international market, the U.S. is now only one among a number of economically important nations. Insofar as few other nations share the U.S. definition of free markets, it is important that U.S. trade policies reflect the realities of the international market and not a theoretical notion of how the market ought to function [3].

In sum, creation of a hospitable climate for technological innovation involves a very wide range of governmental actions. Most of the decisions on these actions take place in committees of the Congress and in agencies with missions little concerned with creating an hospitable climate for commercial technological innovation. This situation can be addressed only by continuous leadership in both the public and private sectors. A new national consensus must be evolved concerning the importance of technology if the necessary climate is to exist.

▾ *Surveying*

The need for continuous innovations, coupled with the lack of adequate theory, requires technology policy include continuous surveying of the global situation. Under these conditions, surveying is a necessary foundation not only for climate setting but also for coordinating and gap filling. In the absence of predictive theory, the only way to improve policy is to observe continuously and gain experience on how government actions affect such essential activities as: development, research, production, and the use of organizational systems and networks. Surveying of this sort requires much more than mere data collection. Effective surveying requires long-term individual and organizational learning. Such learning requires a stable organizational setting. Only long-term assessment of the status and trends in technologies worldwide can provide the knowledge needed to inform the making of technology policy. The wisdom and insight needed to inform policy of this complexity cannot be gained over the short term.

Chalmers Johnson's classic study of Japan's Ministry of International Trade and Industry (MITI) supports this view [23]. MITI, in its early days, made a number of serious mistakes, but over the long term it has learned to be far more effective. More recently, Fumio Kodama identified the ability of MITI to sense and respond quickly to changing conditions as the reason for its continuing importance [24]. MITI's efforts have been guided by experience gained through continuous surveying and not by theory. Currently, The White House Office of Science and Technology is playing a role in surveying commercial technologies as demonstrated in the recent Critical Technologies Report. However, over the longer term, the executive branch of the federal government has had only an on-again, off-again system for surveying needs in the technology policy area.

This intermittent surveying seems to reflect three influences. First is the continuing power of an ideology hostile to any government role in commercial technologies; second, the dominant position of the U.S. in technological industries from World War II until about 1970 seemed to make explicit actions unnecessary; third, the now largely discredited belief that support of long-range science was by itself enough to maintain the U.S. predominance in technological enterprises.

The U.S. has long had technology policies in defense, medicine, and agriculture.

The preceding discussion suggests the need for a far more permanent and stable surveying function for commercial technologies. This view is supported by the record of agriculture, medicine, and defense in the United States. In these areas, a specific agency of the federal government carried on continuous surveying at least since World War II, and used the results to create a policy assisting both incremental and radical innovations. As noted above, these three sectors deliver the majority of products which generate the nation's largest trade surpluses [25, pp. 73, 75].

Surveying commercial technologies is now an essential function because our strongest competitors do it and use the information to guide the next stages of innovation. Without a U.S. surveying function, our competitors enjoy superior intelligence. As Richard Nelson, one of the nation's shrewdest observers of technologically-based economic competition said, our eroding position is not because the U.S. has become less effective in innovation, but rather because our competitors have become far more effective [26].

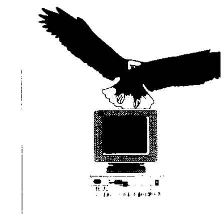
Other nations became more effective for many reasons, and one of them is sophisticated surveying capability. Foreign competitors know that leadership in technological enterprises needs the kind of surveying the U.S. has long maintained in medicine, agriculture, and defense. A stable, ongoing, sophisticated, surveying function is, and will remain, central to an effective U.S. technology policy.

▼ *Coordinating*

The need for coordination flows from two characteristics of much of contemporary technology: current technology is often complex, and it is frequently the product of complex synthesis. Many of the most recent advances in technology arose from fusion of two or more preexisting technologies, or from movement of know-how into areas to which it had not been previously applied. Examples include the integration of computers, machine tools, new software, and changed social arrangements as bases for flexible manufacturing. Fiber optics was achieved by the fusion of know-how in plastics with knowledge about the effects of frequency on transmission within the telecommunications industry. Improved cameras arose from the movement of bar code technology from retail sales into camera designs. A recent example of the creation of a wholly new industry through fusion of older technologies is the creation and rapid diffusion of FAX devices.

This use of ever more diverse expertise and skills in single innovative projects requires the creation of new organizational arrangements which facilitate rapid and flexible coordination. When needed expertise is dispersed among a variety of organizations, assistance from governments may be needed to coordinate these activities, as in many activities in the space program, and in the Manhattan project which created the atom bomb. Governments can, for example, foster such networks via cooperative projects, incentives, and appropriate antitrust policy. A good example of such a network is the system whereby the U.S. commercial aircraft industry used government funded R&D to develop advances in military aircraft. A negative example is the failure of the U.S. machine tool industry to integrate computers with machine tools into saleable products as rapidly and effectively as the Japanese networks did, with a consequent large decline in market share. Part of this failure seems to have come from the splintered nature of the U.S. machine tool industry and part from the lack of computer expertise in that industry. In the absence of any agency or network with a capability and interest in creating the necessary coordination of knowledge and organizations, failure was the result. The needed coordination could have very probably been accomplished without great difficulty by the U.S. government had it had appropriate surveying and an appropriate agency to facilitate coordination.

The coordination function appears common to all nations which are successful in commercial innovation. Contrary to conventional wisdom, governmental coordination often played a central role in the history of U.S. technologies. Among the obvious examples are the creation of the railroads, the highway system, and the air transportation system. In the post World War II period, coordination was essential to success in the aerospace/defense, agricultural, and medical sectors [25].



What specifically is meant by the government coordinating function? Usually it implies government efforts to assure that various organizations which can contribute to a technology know of each other and cán interact without serious barriers. In some cases, the government can take actions to forge important missing links. With few exceptions, government coordination

An effective government role involves assistance and stimulation but not doing.

does not mean direction of the networks by government. To put this differently, top-down control is usually the opposite of what is needed. Once goals have been set, effective work of coordination requires fostering strong lateral communications among the active elements in the network. This implies a process for repeated formation of consensus among the groups with the relevant forms of expertise.

▼ *Gap Filling*

Gap filling is the clearest and the most controversial of the technology policy functions. Gap filling implies the supply of functions or of organizational arrangements that do not exist and are not likely to be filled by commercial organizations. Gap filling has been common in the U.S. in defense, agriculture, and medicine, but has been rare and *ad hoc* in the commercial sector. So long as the U.S. led the world in a very large number of commercial technologies, there was little if any need for gap filling, but that is no longer the case. Gap filling, remains nevertheless highly controversial because it raises the specter of "picking winners." Picking winners connotes at least two negative attributes: 1) supporting commercially unsuccessful products or processes; and 2) giving some companies commercial advantage over others. Gap filling need not, however, involve picking winners in this sense for reasons discussed below. In fact, there are several gap-filling activities which can be very important to the success of commercial technological enterprises that are relatively free of the negative attributes.

Historically, gap filling by governments has taken three forms: direct, contract, and cooperative. The direct mode commonly involves the creation of new organizations by the government to accomplish specific innovations. Such organizations include, for example, agricultural research stations; the National Bureau of Standards; the National Cancer Institute; and the wind tunnel test facilities of the former National Advisory Committee on Aeronautics (NACA). There is general agreement that many of these historic gap-filling functions were quite successful. For example, the wind tunnels of NACA were critical in developing the U.S. aircraft industry, and could not have been afforded by the fledgling aircraft companies in the early stages of the industry. The standards and the tables of properties of materials produced by the National Bureau of Standards played important roles in many industries.

The contract mode involves government funding of other organizations to do specific tasks. It is the norm in military procurement. One such project involved Air Force funding of the first numerically controlled machine tool to improve aircraft production. Orphan drugs are another example. The original support for the development of computers and for production of semiconductors came from the military. Significantly, when IBM first looked at computers, it was not convinced of their commercial utility. Thus IBM played no role in the very early stages, but began developing computers after several military sponsored projects demonstrated their potential, and reduced the risks.

A classic situation which warrants contract support by government is when a missing bit of knowledge or a missing process prevents innovations in larger systems. A large part of the government supported work which can be called "technology-induced-science" carried out in university research groups and non-profit institutions falls into this category. A few examples out of many are the work on high temperature superconductors, on improved processes for clean-up of emissions in combustion systems, and on miniaturization of semiconductor circuits.

In the 1960s and 1970s numerous commercial advances were spun off from contract supported defense innovations. These ranged from the creation of whole industries such as computers, semiconductors, jet aircraft, and microwave devices, to a large number of more detailed advances. These examples illustrate the "trickle-down" effect. In earlier decades, when there was little foreign competition, such trickle down effects were sufficient to create leading positions for U.S. industry in many technologies. However, the trickle-down effect is not adequate in the face of serious foreign commercial competitors. Given strong competition, trickle down is at best inefficient and at worst insufficient as the source of commercial innovations.

An organization which is noted for its successes in filling gaps employing the contract mode is the Defense Advanced Research Projects Agency (DARPA). DARPA has a charter to do gap filling in the military sector. DARPA surveys technologies, and makes projections about technological trajectories. It then funds high risk projects which have high potential for improving military systems. Since it is a part of the U.S. Department of Defense (DOD), DARPA exists within a network which does continuous surveying of technologies and which has connections to many U.S. institutions. The rules by which DARPA chose projects and created many successes are in no way secret; they were recently summarized by Craig Fields, a former director [27]. DARPA stands as a powerful counterpoint to the notion that government inevitably makes wrong choices in supporting technological trajectories of future importance.

The cooperative mode in the U.S. is of more recent origin, and its initiation was heavily influenced by patterns developed in Japan (e.g., the VLSI project) and in Europe (e.g., the EUREKA project) where there are long traditions of cooperative work. In the cooperative mode, government acts to support companies in creating a consortium in order to work on a problem seen as important to the nation. A recent U.S. experiment is SEMATECH, a consortium focused on the development of semiconductor production processes.

Gap filling via consortia created to work on generic technologies most closely approaches picking winners. But this form of gap filling is often attractive for two reasons. First, support for generic technologies is warranted in areas of important promise in which the cost and risk of the R&D necessary for the next round of innovations are too great for single firms to assume. The function of government is then to aid in reducing the risk and the cost to a point at which individual companies can take over. Second, it is far easier to foresee the impact of technological trajectories than to decide what specific products or processes will be "winners" within a given technological trajectory [28].

Consortia of this type can serve a number of purposes. First, and perhaps most important, they can highlight the developing technologies which will be important in international competitions for the next generation of products in one or more sectors. As noted above, this need not involve picking a winning process or product, but rather can be centered on reducing risks by work on generic technologies thus delineating the direction which product designers need to follow, and the constraints they need to recognize, for successful developments.

If consortia are to be effective, it is critical that they be organized to increase, rather than decrease, downstream competition among the companies involved. The Japanese were able to achieve this increased downstream competition by insistence on "shadow projects" within the participating companies. A shadow project is a group of engineers who remain within the home company but follow the work of the consortium actively. The word "actively" implies that the home group contributes to the idea generation within the consortium, visit the consortium relatively frequently, and also replicate critical experiments and processes at the home company facilities. This active following creates two conditions that are essential to later transfer of the technology: 1) there is a group at the home company with deep hands-on expertise; and 2) the home group remains integrated in the company network and can therefore act as in house champions for the developing technology, thus securing sufficient priority to activate appropriate projects in a timely manner.

Because of rapid product and process innovation, much gap filling needs to be transitory in nature. Some projects should start and end at predetermined dates to preclude their perpetuation beyond a useful cutoff time. Gap filling depends on current information and thus is especially dependent on intelligent surveying. This surveying is in turn dependent on the networks which facilitate prompt flow of information.

▼ *The Interrelationship of Functions*

Perhaps nothing is more evident from the preceding discussion than the interrelationship and interdependence of the four functions. Thus, any effort to formulate a technology policy without addressing each of the functions will likely lead to a crippled policy and program.

Unavoidable Policy Decisions

Advanced nations cannot avoid the many policy decisions which together create a more (or less) favorable climate for innovations. This climate strongly affects the health of technological enterprises operating within the nation's borders. Thus, a technology policy will exist in any advanced country. The relevant question, therefore is "How will policies be created?" At one extreme, policies can be created implicitly through a series of *ad hoc* indirect responses to various crises and by many decision makers whose primary concerns are not commercial technology. At the other extreme, policies can be formulated in a direct, self-conscious way which provides opportunity for explicit formation of consensus on the issues which affect the national interest among the interests involved.

Over the past few decades, the U.S. has largely employed the implicit, *ad hoc* mode in the commercial technology sector. The Japanese have primarily employed the explicit mode. This comparison speaks strongly for the value of explicit policy formation.

Similarly, over the post World War II period the U.S. has benefited from direct, well developed technology policies in the areas of defense, medicine, and agriculture. These policies produced not only U.S. technological leadership in the three sectors but these sectors also contributed most of the large trade surplus generating products during the 1980's. Commercial technologies, by comparison, experienced poorer performance. This comparison argues strongly for the value of direct, self-conscious formulation of technology policies.

An adequate technology policy needs to serve four interrelated functions: climate setting; surveying; coordinating; and gap filling. A lack of clear delineation of these functions in the past tended to confuse the debates needed to reach appropriate decisions about government support of technologies in the commercial sector. Inasmuch as some of these functions are unavoidable, and others can be carried out using a wide range of instruments, clear delineation is important.

Exercise of the four functions of technology policy by the U.S. government requires action of two fundamental kinds. First, attaining and maintaining competitive commercial technologies must become a national consensus, high priority goal. This will require that the President and the Congress, by both word and deed, impress on the nation the centrality of competitive technologies to a high national standard of living and thus to the achievement of many other national goals.

Second, the government needs to establish and maintain a sophisticated institutional capacity for surveying the global situation and trends in technology. It then needs to use the knowledge generated through surveying to facilitate consensual decisions about technology policies in many other parts of government, and to issue appropriate decisions regarding coordinating and gap-filling actions.

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shift in the values and myths (in the anthropological sense) of our culture. These are important dimensions of any move toward a more sustainable way of life. We also need to focus on the contribution the engineering profession can make if it accepts the need for preventive engineering.

Acknowledgment

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