Chapter III

U.S. EXPERIENCE

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This chapter is concerned with documenting the status and effect of U.S. Government policy regarding technological innovation. It presents factual information about which programs exist and suggests a framework within which to consider their effects.

The task has been approached from two perspectives. One, a "program perspective, " concentrates on the documentation of existing U.S. programs and policies that have an important relationship to technological innovation. These have been organized into a series of 13 major policy areas and are presented in *Government Programs, see* below. The second approach, an "industry perspective, " focuses on a series of industrial sectors and considers what have been the effects of Government action on innovation in those sectors. This is presented in *A Comparison of Selected Industry Experiences,* p. *35.* The presentation of two different perspectives illustrates an important premise of this report—that a full understanding of the Government-innovation relationship must involve an appreciation not only of the existing programs, but also of the industrial contexts in which their effects are felt.

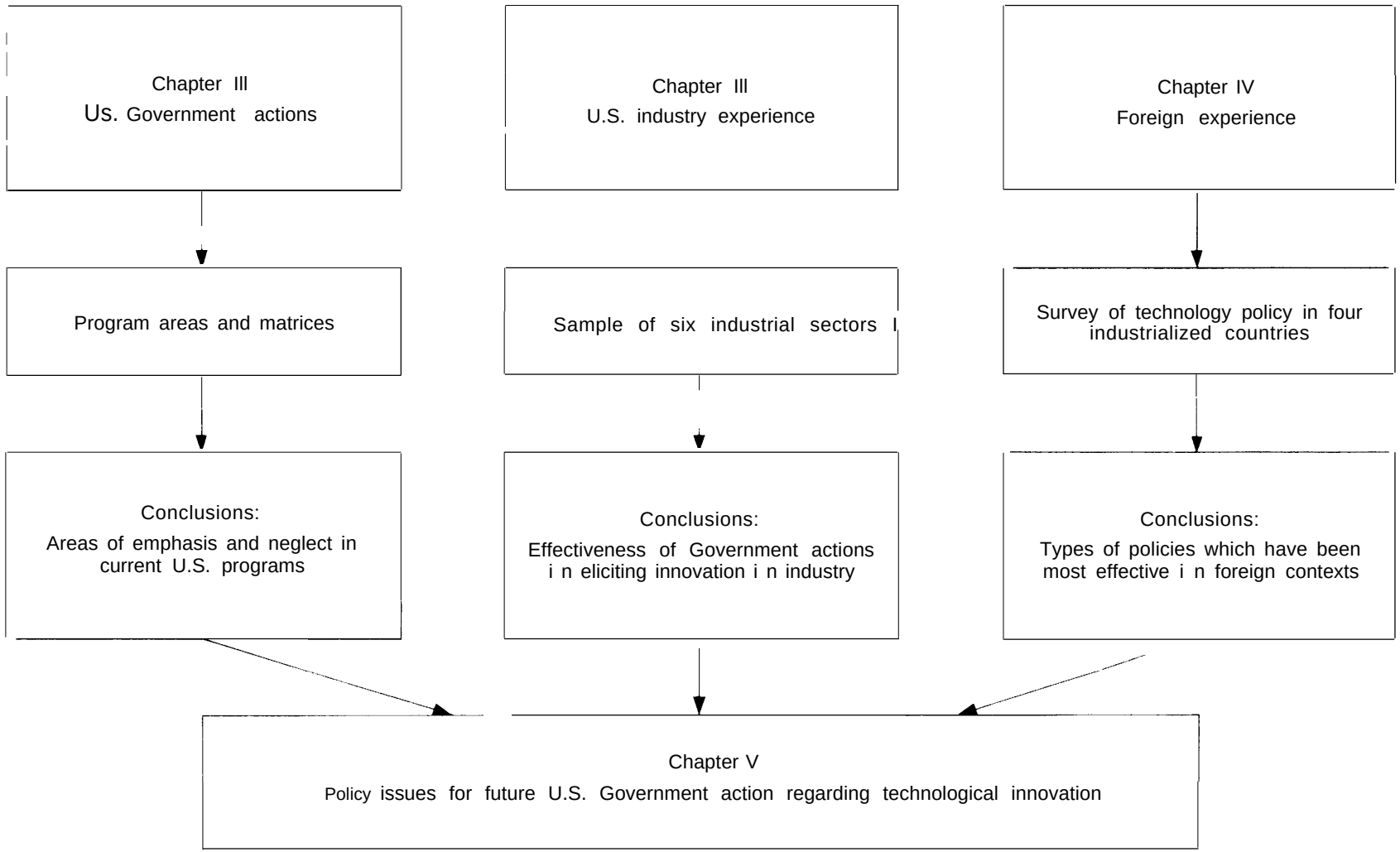
Although the presentation of each perspective contains a large amount of factual information, detailed analysis and evaluation have been eschewed in favor of a broad overview. This approach was chosen in order to be consonant with the overall focus of the report on the development of policy issues. Each of the perspectives has been utilized extensively as a source from which to draw in the development of the policy issues presented in chapter V. Figure 2 illustrates the components of this section and their relationship to the other parts of the report.

GOVERNMENT PROGRAMS

A Framework for Viewing U.S. Government Programs and Activities

The U.S. Government programs with which this report is concerned are those that have an important relationship to technological innovation. The number and variety of such programs are very large, and many, if not most, are not intended to affect innovation. On the contrary, the programs are directed toward a diversity of societal goals, some of which include: increasing the availability of goods and services for a variety of purposes, protecting society from the adverse consequences of technology such as endangerment of health and safety or dislocation of manpower, and designing measures benefiting specific sectors such as manufacturing, small business, labor, consumers, or the disadvantaged. These goals represent sometimes conflicting purposes. and the particular programs and activities directed toward them are undertaken somewhat independently of each other. Nevertheless, it is useful and necessary for conceptual purposes to establish a framework for organizing the Government programs and activities into a number of self-contained program areas which reflect the major technology-related themes of the programs that seem to be important or are at issue.

Figure 2.— U.S. and Foreign Experience
(Sources of Issues for Technological Innovation Policy)



SOURCE: Center for Policy Analysis

A framework of this kind is valuable for several reasons. First, it provides a convenient construct for viewing the large number of relevant programs. Second, it illustrates some aspects of the programs' relationships to technological innovation. Third, it provides a common structure within which the proponents of various viewpoints can make their case concerning a reorientation of national policy in relation to technology.

PROGRAM AREAS

The framework developed for these purposes is presented below. The 13 program areas are listed in table 1. They have been organized according to the following logical sequence.

- Area 1, *technology assessment,* is basic to policy design. Ideally, Government must be able to assess specific technologies with regard to their utility, unintended consequences (externalities), and the distributional consequences of both utility and externalities, if specific programs or activities are to be continued, altered, or initiated.

Area 11 addresses the *direct regulation of the innovation process* through constraints on the research and development of new products and processes. Regulation here is intended to ameliorate the adverse consequences of technologies. The design of policy in this area is concerned with the problem of externalities and distributional consequences of possible adverse health or environmental effects.

- Area ☆☆☆ focuses on direct regulation of the *production, marketing, and use of new or existing products.* The purposes and methods of regulation in this category do not differ substantially from area II. However, because regulation here focuses on end products rather than the development process, its impact on innovation is more indirect. The numbers of regulatory programs in this area are quite large and exceed those in area II.

- Area IV addresses the activities and programs that are intended *to enhance the development and utilization of technology for private goods and* services *where the* private *sector is the* primary *user.* The Government role in this area has traditionally been a relatively limited one.

- Area V concerns programs to support technology *in public services* where consumers *are the* primary *users.* In contrast to area IV, the Government role here has traditionally been rather large. Public goods and services such as transportation, communication, or law enforcement comprise the relevant programs.

- Area VI represents *technology enhancement activities where the Government itself (on behalf of the society) is the prime user.* This area would include programs such as the space and defense efforts.

The program areas 11 through VI all represent activities and programs that are undertaken in order to directly affect a perceived deficiency in resource availability, utility, externalities, or distributional consequences of technological activity. Areas 11 and 111 consist of programs in which regulatory means are employed to channel the direction of technology, and areas IV through VI consist of programs that utilize other mechanisms to enhance the development of technology. The remaining seven program areas represent activities that are less direct, though important for technological change.

- Area VII is the list of programs generally described as the necessary *infrastructure or* science *base* required -for innovation to occur, for whatever purpose. This includes programs such as support for basic research, information transfer efforts, etc,

- Areas VIII and 1X represent less technology-focused policies, emphasizing policies directed toward industry and labor market structure respectively, which nonetheless may affect technological change.

- Areas X and XI represent even more general *domestic economic and*)oreign *trade policies* with possibly unintended or indirect effects on technological innovation.

- Area XII concerns programs that create shifts *in the consumer demand* for technologies. Various regulatory policies, user subsidies, and information transfer programs operate in this area as modulators of existing market forces and hence exert an im-

portant impact on the kinds of new technologies developed.

- Area XIII similarly concerns worker *demands* that are likely to influence the nature of new technologies. The demand for safe working conditions is one example.

The programs in areas 11 through X1 all focus primarily on supply-side Government programs and activities, intending to affect what the industrial or labor sectors are able to deliver. In contrast, areas XII and XIII emphasize the demand-side policies directed towards enhancing the expression of consumer and worker demands respectively.

Because the 13 program areas reflect independent, and sometimes even conflicting, societal goals, there are difficult choices to be made concerning the relative emphasis among them. Accordingly, the choice of which areas deserve more or less attention is necessarily a political determination, which might be very different if made by those concerned primarily with industrial growth in contrast to those interested in environmental pollution. What the organizing of Government programs and activities into these 13 groups permits is a discussion as to relative policy emphasis that makes clear the priorities of the group proposing expanded or diminished attention to various areas. The categorization of activities into these policy areas should itself evoke little controversy and will allow the different perceptions of what deserves greater or lesser emphasis to be advocated within a common framework.

Identification of U.S. Programs

The following section identifies and categorizes existing U.S. Government programs that have an important relationship to technological innovation. This is done through the use of 13 matrices, each of which corresponds to one of the 13 program areas. The matrices were developed in order to illustrate something of the nature of the relationship between the programs and activities which comprise the policy areas and technological innovation. This is accomplished by the axis labels for each matrix. For example, in area I, which concerns technology assessment, the primary evaluative questions with respect to a new or existing technology—its utility, external effects, and the distribution of its effects to different segments of society—are listed on the horizontal axis. Similarly, in area IV, which concerns technology enhancement in the private sector, the various mechanisms for encouraging new technologies—transferring information, reducing cost, increasing the reward, etc. —are listed on the vertical axis.

For each program area, the matrix entries represent an attempt to identify the major existing programs and agency actions. Because many, if not most, Government activities are addressed to more than a single purpose, programs often appear in more than one matrix. It should be emphasized that although the programs listed clearly differ in terms of their size and effectiveness, information as to their relative weight is not contained in the matrices since the primary purpose of the matrices is to identify and categorize rather than to evaluate.

The matrices were a valuable tool to the analysis in several respects. First, they provided a convenient structure for categorizing the large amount of data gathered about the existing U.S. programs. Although the programs are listed without annotations in the matrices, substantial background research and analysis went into their categorization and the matrix development. This effort, though relied on to reach the research conclusions, is not presented in this report. Second, the matrices allowed the areas of programs emphasis to be highlighted, both among the 13 policy areas and within each area. Third, they furnished an analytical tool which was relied upon heavily in developing the major policy issues presented in the final section of this report. Those issues are all concerned with possible reorientations of existing national priorities.

The matrices were important, therefore, in suggesting where existing emphasis lies and what kinds of programs have generally been neglected. For example, in matrix IV, which concerns the encouragement of private-sector technological development, it became apparent from the categorization of existing programs that there is no major, across-the-board program in support of basic civilian technology. The realization that there is a lack of such a program, when combined with information about the foreign experience in this regard, led to the suggestion that new programs of this kind should be considered as a

Matrix L-The Assessment of New and Existing Specific Technologies*

Reason for undertaking assessment	Subject matter of assessment: Utility	Externality	Distributional effects
Explicit or primary mission agency	ı Full assessment studies: – OTA —— *		
	– GAO —— *	. Assessment as to safety: CPSC, NHTSA, FDA, OSHA, NRC . Assessment as to environmental effects: EPA (TOSCA), CEQ • Assessment as to inflation: CWPS	
Incidental to primary mission, but a recurring function	ı Part of cost-benefit or other program analysis or evaluations by mission agencies, e.g., DOT, DOD, NASA, DOE —— *	. Impact statements by mission agencies: —environmental (E IS) —economic (inflation)	
Ad hoc	ı Special commissions or studies: e.g., NASJNAE saccharin study —— m		
	Special studies by mission agencies, e.g., FCC electronic mail assessment, NSF funding		

● OSTP is responsible for assessment or coordination of agency technology policies rather than assessing specific technologies

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Matrix II.— Direct Regulation of the Research or Development of New Products and Processes

Manner of action	Purpose of Program: Control of health/safety hazards	Control of environmental hazards	Safeguard of national security
Outright suppression of R&D	. Research on highly infectious agents		• Nuclear weapons research
Limited granting of license/permit for R&D	• Research on certain radioactive materials (DOE)	. Research using fast-breeder reactors (DOE) —————* • Research on nuclear fuel reprocessing —-~ ~	• Research on uranium isotopes separation (DOE)
Setting standards/ requirements for R&D	. Research using human subjects (HEW) • Pharmaceutical research (FDA) ————+ s Pesticide research (EPA) ————* . Food additives ————F . Research on toxic substances (EPA) ————P . Medical devices (FDA)		
Setting guidelines for Federal funding of R&D	• Recombinant **DNA** research (N1 H)		
Voluntary guidelines	• Recombinant DNA research		

Matrix III.— Direct Regulation of the Production, Marketing, and Use of New or Existing Products

Regulatory area	Commercial stage affected: Production	Marketing	Use
Pollution control	• Air pollution (EPA) —stationary sources — mobile sources • Water pollution (EPA) —effluent —drinking . Noise pollution (DOT, EPA, OSHA)		
Health/safety standards	• Workplace (OS HA) • Toxic substances (EPA) . Drugs (FDA) • Pesticides (EPA)	. Labeling —consumer products (CPSC) –pesticides (EPA) • Advertising control, e.g., cigarettes (FTC) Consumer product safety standards (CPSC) . Automobiles (NHTSA) . Drugs (FDA)	• Pharmaceuticals (FDA) • Food additives (FDA) • Pesticides (EPA) . Transportation safety (DOT) • Radioactive materials (NRC)
Product specification	• Automobile fuel efficiency (EPA, DOE, DOT) • Appliance energy efficiency (DOE) • Coal conversion, energy conservation i n manufacturing (DOE)	• Food inspection and grading (USDA, FDA, DOC) • Packaging and labeling specification (FTC)	• Communications regulation (FCC) • Building codes (HUD) • Product standardization (NBS)
Products liability	• Tort system →	→	→

Matrix IV.- Programs To Encourage the Development and Utilization of Technology in and for the Private Goods and Services Sector

Manner of action	Stages of innovation process: Market research	Technical research	Development/ engineering	Production and commercialization
Transfer of technology to the firm		. Antitrust regulat ions joint R&D (antitrust exemption) —compulsory licensing . Tech. Ut il. Program (e.g., NASA, SBA) . Diffusion program of R&D from Government labs . Diffusion of R&D funded by Govern- ment (e.g., ASRA, NTIS) . Agricultural extension services . Govern ment-univer- sit y-industry coopera- tion (e.g., Sea Grant)		
Reducing costs of innovation		. Direct funding of R&D (e.g., DOE) . Tax treatment for R&D • Antitrust regulations —licensing –joint R&D (SBA) • Compulsory licensing under Government procurement Q Agricultural extension services	. Investment tax credits	. Loans and subsidies for modernization (e.g., fisheries and shipbuilding)
Increasing reward of innovation		. Patent and I icense system Government procurement		
Decreasing probability of commercial failure	Government procurement Provision of market in- formation (DOC, SBA)		• Demonstration projects	
Decreasing probability of technical failure		• Provision of technical information (e.g., NTIS, other mission agencies) • Invention evaluation (DOE/NBS)	c Demonstration projects	

Matrix V.—Government Support of Technology for Public Services*
Where Consumers are the Primary Users

Manner of Government action	Element of innovation process affected: Market research	Technical research	Development and engineering	Production and commercialization
Reducing private sector costs	Direct funding of R&D (e.g., EPA, DOE, DOT, DOC) —*		• Provision of capital (e. g., CO MSAT) —*	
Government performance	Studies of consumer demand (e.g., DOT)	c R&D by national and agency labs	• Demonstration projects (e.g., DOT, DOE)	
Increasing private sector reward	Government procurement —→ ~ Rate-of-return regulation (e. g., utilities) —→			• Regulations limiting entry (e.g., FCC, CAB)
Reducing probabilit~ of failure	• Government procurement specif i cat ions —b		c Demonstration projects	
Diffusion	~ Publication of market studies (e.g., mission agencies)	• Technology transfer programs (mission agencies)		
Influencing demand				c Government user subsidy (e. g., tax incentives for horn insu l at ion) • Specification of approved product: (e.g., medical devices)

"Program areas: Law enforcement, health, transport, communications, energy, education delivery, pollution control delivery.

Matrix V1.—Support for the Development of Technology Where the Federal Government is the Primary User

Manner of action \ Stage of innovation	Research	Prototype development or demonstration	Manufacturing/ production
Product procurement	c DOD (e. g., lasers) . NASA (e. g., space systems) • Other mission agencies (i.e., EPA, DOT, etc.)	• DOD (armed services) • NASA (e. g., shuttle program)	c DOD (weapons procurement) • NASA (e. g., spacecraft components)
Support for R&D in the private sector	• DOD (mainly DAR PA) • NASA c Other mission agencies	• DOE (fusion research) • DOD (mainly armed services)	• DOD (e. g., ICAM program)
Performance of R&D by the Government	. DOD (service labs) . DOE (energy research centers, National Labs) • Other mission agencies	• DOD (e. g., weapons development) • **DOE (e. g.,** fusion, uranium enrichment)	• DOD (weapons procurement) . DOE (nuclear weapons)

Matrix VII.—Support for the Science Base Necessary for the Development of New Technology

Activity supported	Government action: Government performance	Government action: Government support
Education	• Military academy science programs (e.g., West Point)	Fellowship program (e. g., NSF, NIH) • Military training programs i n private institut ions • Support of university research
Basic research	c NBS (e. g., laser research) NIH • NASA	NSF • DOE (e. g., high-energy physics) * w
Data compilation and validation	Federal data banks (NBS) • Mission agencies	• Support for data compilation —as a component of overall scientific effort (NSF, NIH) —related to specific problems (N AS)
Dissemination of research results	• NTIS	• Support for scientific publications, conferences (NSF, NI H)

Matrix VIII-Policies To Affect Industry Structure Which May Affect the Development of Technology

Aspect of industry structure affected	Nature of effects: Motivation to innovate — Increase	Motivation to innovate — Decrease	Ability to innovation — Increase	Ability to innovation — Decrease
Entry-exit	• Bankruptcy laws • Tax-loss provisions	• Compulsory licensing actions Barriers due to patent rights	• Tax loss provisions	• SEC regulation
Competitive position of small firms	Procurement earmarked for small businesses	. Capital gains treatment • Access to venture capital (Sec. 144)	• Subchapter S (IRS code) • SBA loans, guarantees • SEC special exemptions SBA joint R&D exemption	• Capital gains treatment • Access to venture capital (Sec. 144)
Relative market dominance of larger firms	Holder's patent rights → Government procurement Antitrust laws —	• Compulsory licensing act ions	• Government procurement Antitrust laws —	
Collaboration among firms	Antitrust laws →		• SBA joint R&D exempt ion • Antitrust laws →	

Matrix IX.—Policies Affecting Supply and Demand of Manpower Resources Having an Impact on Technological Change

Characteristic affected	Principal group affected: Employers	Employees	Educational institutions
supply		• Retraining programs • Immigration policy	• Government-funded scholarships c Federal support for vocational and technical training
Demand	• Tax credit for new employment generated b Government procurement • Government-funded R&D		. Government-funded R&C
Price	• Minimum wage Q Social security taxes • Tax credit for new employment		
Distribution	• Regional development incentives s Sectoral development incentives	• Tax provisions for moving expenses	
Mobility	• Tax credits for retraining programs	• Labor adjustment assistance . Industry-Government exchange programs	s Federal support for vocational/technical training

Matrix X.—Economic Policies With Unintended or Indirect Effects on Technological Innovation

Policy type	Area affected: Motivation to innovate	Area affected: Ability to innovate
Macro-economic policy	. Government budget Minimum wage legislation Social security taxes	Interest rate
Capital market transactions	. SEC rules and regulations →	Banking regulations • ERISA provisions on venture capital investments
Regulatory measures	. Regulated rate structures (e.g., ICC)	
Tax policies	. Tax writeoff for losses • Investment credit . Depreciation allowance • Capital gains preference . Depletion allowances →	* b

Matrix XI.—Policies Affecting International Trade and Investment

Area affected	Direction of effect: Tend to encourage	Direction of effect: Tend to discourage
U.S. import	. M FN status on tariffs . Adjustment assistant program —labor —business . Tariff concessions • GATT	. Tariff barriers (ITC) • Product safety standards (e. g., FDA) • Import quotas • Government procurement (Buy American) • Industrial standards • Antidumping duties . Counterveiling duties . 200-mile limit on fishing rights . STR (Special Trade Representative)
U.S. export	Government subsidies (e. g., on agricultural products) • Export exemption of product safety regulations Tax concessions (DISC) • Export credits (EXIM bank, Commodity Credit Corp. of DOA) • Loan guarantees by EXIM bank to private credit sources (PEFCO, FCIA) • Tied foreign aid (AID) • Export promotional information service (DOC)	Export Administration Act Munitions Control Act • Trading with Enemy Act . Anti-Boycott legislation
U.S. investment overseas	• Tax credits on foreign taxes paid • Tax deferrals (e. g., subpart F income) . OPIC guarantees . Pollution and safety standards on U.S. plants • Transfer pricing control (IRS code 482) → • Allocation of R&D expenses (IRS code 1.861)	• Extraterritorial application of antitrust
Foreign investment in United States	Mechanisms discouraging i m ports may encourage investment i n United States Exchange ratesetting →	. Pollution and safety standards on domestic plants → . Industries closed to foreign investment (nuclear energy, communications, shipping)

Matrix XII.—Policies Intended To Create Shifts in Consumer Demand

Manner of action \ Policy purpose	Protecting health/safety	Protecting economic welfare	Other social purposes
Regulation of product characteristics	Consumer products (CPSC) . Toxics, pesticides (EPA) Food, drugs (FDA) • Food (USDA) . Cars (DOT)		. Energy efficiency standards: cars, appliances
Regulation market transactions		Consumer credit regulation . Warranty regulation . FTC enforcement against deceptive trade practices . Advertising regulation, (e.g., corrective advertising)	
Information transfer	. Nutritional labeling Warning labels (e. g., cigarettes)	• Food grading (USDA) . Regulation of credit Warranty regulation . Fair packaging and labeling	• Energy labeling
Financial incentives			. Tax credit for pollution-control devices

Matrix XIII-Government Policies Responding to Worker Demand Having Impact on Technological Change

Manner of action \ Policy in response to:	Demands for health/safety	Demands for economic welfare	Demands for legal rights
Regulation	. Working conditions: –OSHA —mine safety regulations	. Social Security benefits • Minimum wage Protection of pension earnings (ERISA) . Raising retirement age	. NLRA
Government information transfer program	• OSHA	. Ajustment assistance (DOC, DOL) . Retraining	

major policy issue (see issue #l, chapter V). Similarly, an analysis of the programs in matrices 11 and 111, which concern regulation, led to the realization that there are various approaches to regulatory design which have not yet been seriously attempted as **a** means of encouraging the development of new compliance-oriented technology. Some of these means were suggested as **a** regulatory policy issue (see issue #5, chapter V). It should be emphasized that the matrices did not provide the only input to the development of issues. On the contrary, the industry studies below and the foreign experience (chapter IV) were also important. The matrices did, however, furnish the principal structure for depicting and analyzing the existing U.S. Government effort regarding technology.

A COMPARISON OF SELECTED INDUSTRY EXPERIENCES

The industry-by-industry study presented in this section was undertaken to complement the policy-oriented approach described previously. On the one hand, it provides a needed "real-world" input into what would otherwise be a rather theoretical construct. Thus, not only does

it serve to identify influential governmental policies, which might otherwise be overlooked (for instance, decisions concerning the allocation of the radiofrequency spectrum by the Federal Communications Commission that have had an enormous impact on innovation in the electronics industry), but it also helps to order such policies according to the observed magnitude of their effect on innovation.

On the other hand, those policies, programs, or procedures that have an indirect or long-range impact, or that affect innovation primarily through their effect on the business environment within which firms innovate, are unlikely to be accorded their proper weight in a microcosmic study concentrating on a particular industry. Furthermore, examination of an industry that has fared relatively poorly in recent years is likely to bias the results toward those Government policies having a net negative effect on innovation, whereas the opposite may be true of industries whose track record is more favorable. In short, the two approaches—macroscopic by policy area, and microscopic by industry—are complementary and have quite different strengths and weaknesses.

Six industries were chosen for study:

- Aircraft and aircraft engines,
- Automobiles,
- Carpets,
- Synthetic materials,
- Iron and steel, and
- Semiconductors.

They were selected based on the existing resources of the Center and the need to include as wide a coverage as possible of the areas examined in the preceding sections.

The conclusions below are only a first step. Little evidence was available on consumer goods and services, and this was especially so when the primary question of the impact of Government programs and actions on innovation was raised. It would be most desirable to broaden the examples considered in a future comparison, beyond those of industrial goods and consumer durables listed above.

This section of the study has been based entirely on secondary sources; books, dissertations, and papers describing the various industries, which were chosen to reflect a long-term view of each industry and the effects on it of various governmental actions over a period, preferably, of several decades. Wherever possible, an attempt has been made to isolate those Government policies and programs that have had a clearly traceable effect on technological innovation in the industry under study, rather than, for example, those mainly affecting its structure or overall economic situation.

Certain limitations of this study must be identified at the outset. The most immediate of these stems from the relatively small number of industries examined. Many more could profitably have been studied, time permitting, and a sample more representative of the economy as a whole could have been obtained. Even within a given industry, this methodology may have emphasized certain forms of Government action over others perhaps equally important in the long run. The self-imposed limitation of examining only those actions that can be shown to have caused measurable change in the technological character of an industry's products or processes may understate long-term, indirect, and incremental effects. Thus, no mention is made of antitrust law as it has affected the automobile industry simply because an effect on technological innovation that flows from it cannot be clearly identified. Similarly, the impact on the industry of federally subsidized highway construction is easily substantiated, but its specific effects on innovation are difficult to document, and have not been included.

There are clearly gainers and losers from any innovation. A new product or process technology may strengthen some firms' competitive positions at the expense of others. Ancillary changes which are both positive and negative may also occur. Only the fact that an innovation occurred is examined here with no attempt to say that net results were positive, The weight of evidence in general supports the assumption that product and process innovation contributes strongly to the longrun vitality and viability of the economy.

Within the limitations stated, we are quite confident about the conclusions reported. Multiple sources of evidence were consulted in each case.

'W. R. Maclaurin, *Invention and Innovation in the Radio Industry (New* York, Macmillan, 1949).

Direct and documented relationships were sought, and for the most part the conclusions are supported by other independent studies.

A general overview of the six industries studied reveals the expected industry-to-industry differences, but also points up some striking similarites—particularly if attention is limited to those forms of governmental initiatives as described in policy areas 111 and VI in this chapter—that seem to be the most effective in inducing technological change. These three are:

- Regulation (pollution, health and safety, energy conservation),
- Federal R&D support (direct to industry, indirect, and performance by Government), and
- Purchase of innovative technology-based products.

Although other governmental actions (e.g., international policies) were identified that had an effect on technological innovation in some industries, and although certain industries (e. g., the carpet industry)[2] seem to have been relatively unaffected by any of the actions outlined above, these three stood out as the most important for those industries in which innovation has been most closely tied to Government action. In other words, these mechanisms were found to be the ones most effective in affecting the rate and direction of technological change in those industries most responsive to Government initiatives.

An earlier study of foreign experiences in encouraging innovation based on over 150 cases in five industries reached identical conclusions. One additional program, Government assistance in technology transfer, was noted as important in interviews conducted in Europe and Japan, but not mentioned prominently in the United States. [3]

The earlier work in Europe and Japan concluded that strikingly different patterns of government influence on innovation were apparent in the five industries studied. This is certainly true in the United States as well. Different actions and programs clearly are of vastly different importance in the six industries examined. Varying effects were also noted in newer as opposed to older firms in these industries, and consequently on different groups of employees, regions, and products. For example, defense procurement and Federal support for R&D in industry have shaped both the semiconductor and aircraft engine industries. Federal performance of R&D was also an important force in the latter case. Product regulation in the areas of emissions, safety, and fuel economy has shaped recent changes in the auto industry, while energy pricing policies have influenced synthetic materials—regulation of processes in the areas of energy conservation, safety, and environmental quality have been important factors in iron and steel investments and innovations. Also, higher minimum wages were held to have speeded introduction of new equipment in the carpet industry, while restrictions on wool imports hastened the use of synthetic fibers.

Actions that help new firms and ventures get started are highly effective in encouraging major innovations. Government purchases and support for R&D have been particularly important in this regard. For example, defense procurement and support for R&D stimulated the entry of new firms into the electronics industry in several ways, primarily through direct purchases. By providing an initial market and premium prices for major advances, defense purchasers speeded their introduction into use. The main contribution to the most important innovations in electronics and especially the development of integrated circuits seems to have been through this means. [4] A similar pattern of rapid technological advance, many new entrants, and economies resulting from production experience economies was evident for aircraft engines. The early establishment of air-cooled engines in the United States can be attributed to new entrants. None of the established engine manufacturers undertook the development of these engines until either persuaded to do so or extensively assisted by their governments.5

[2] Jinjoo Lee, *The Evolution of Technological innovation* in *the Carpet* industry (Cambridge, Mass.: MIT Center for Policy Alternatives working paper, January 1978).

[3] *National Support for Science and Technology:* An *Evaluation of the Foreign* Experience (Cambridge, Mass.: MIT Center for Policy Alternatives).

[4] James M. Utterback and Albert E. Murray, The *Influence of Defense Procurement and Sponsorship of Research and Development* on the Development of the *Civilian* Electronics Industry (Cambridge, Mass.: MIT Center for Policy Alternatives (CPA-77-5), June 1977).

[5] R. Miller and D. Sawers, The Technical Development of Modern *Aviation* (New York, N. Y,: Praeger, 1970).

Government procurement has played a significant role by establishing aircraft designers as commercial innovators. For instance, Douglas, which introduced the most successful DC-3 in the mid- 1930's, spun off from Martin in 1920 and started as a military aircraft designer. Vickers developed the Viking and Viscount from experience gained from the Wellington bomber. Boeing was largely a military supplier before it built the 707, one of the first successful jetliners. [6]

These few examples certainly do not mean that encouraging entry through procurement would have a positive effect in every case. In a product area with little commercial growth potential, such a policy might simply lead to instability and greater uncertainty for the participants. The argument is that purchases by Government have great strategic leverage in stimulating innovations in many instances when this is understood and considered.

Actions that complement normal competitive pressures for change in an industry often appear to be more effective in promoting innovation than those that do not take account of market forces. For example, while the minimum standards for auto-emission control tend not to be exceeded, industry has met fuel economy standards well in advance of what has been required. [7] The difference seems to reflect the degree to which market forces and regulatory requirements are in concert in the case of fuel economy. In such cases industry is doubly motivated to innovate. Requirements for energy saving in steelmaking are also in line with the industry's competitive concerns with productivity and costs. As fuel is a major part of total production costs, conservation requirements and competitive forces have acted together to stimulate change. [8] Conversely, pollution-control regulations and the current tax treatment for pollution-control expenditures appear to have simply encouraged retrofits on existing facilities instead of investment in newer and more efficient technologies. [9]

There is a strong suggestion here that an effluent charge or heavy penalty above some minimum total-plant discharge would act in concert with competitive forces and encourage innovation, while a host of specific requirements work against competitive forces and also discourage innovation. [10]

Many creative departures from continuing incremental improvement of existing technology seem to be the result of firms' responses to crises. A crisis forces the firm to search in new directions for solutions. It can result in major losses and failures, but also can result in unexpected solutions. For example, a new process for making stainless steel using less chromium was introduced when imports of Rhodesian products were restricted. Also, steel firms joined together to develop new ore beneficiation methods when diminishing supplies of high-grade ore in the Great Lakes region threatened their economic survival. [11]

Some evidence suggests that direct regulation of products and processes may act as a crisis to accelerate major innovation. 12 For example, the use of electronic microprocessors to control auto engines is a major innovation to address needs for both fuel economy and lower emissions levels. New technologies sometimes open great potentials for expansion of their application and for improvements, in this case for other electronic automotive applications such as controlled braking. And it should be noted that while costs will be higher for automakers and consumers, a large market has been created for firms making microprocessors, sensors, new auto accessories, etc.

The timing of regulatory interventions is critical regarding their influence on technology and in-

[6] Linsu Kim, The *Influence of Government on Technological Development* in *Aircraft* and *Aircraft* Engines (Cambridge, Mass.: MIT Center for Policy Alternatives working paper, December 1977).

[7] William J. Abernathy and Balaji S. Chakravarthy, Tech*nological Change* in *the U.S.* Automobile Industry: Assessing *the* Federal Initiative (Cambridge, Mass.: prepared for Department of Transportation, Transportation Systems Center, December 1977).

[8] Linsu Kim, The *Influence of Government Actions on Technological Development* in the Iron and Steel *industry* (Cambridge, Mass.: MIT Center for Policy Alternatives working paper, January 1978).

[9] Joseph Mintzes, *Technology and World Trade: The Steel Industry,* a paper prepared for OTA, May 19, 1977.

[10] W. J. Vaughn, C.S. Russell, and H.C. Cochrane, *Government Policies* and the Adoption *of Innovations in the Integrated Steel Industry* (Washington, D. C,: Resources for the Future, 1976).

[11] Kim, 1978, op. cit.

"Thomas J. Allen, et al., "Government Influence on the Process of Innovation in Europe and Japan, " *Research* Policy, (in press).

[13] George White, "Management Criteria for Technological Innovation," *Technology* Review, February 1978,

novation. Unless the needed infrastructure, such as trained people, is in place or created concurrently to meet the requirements, severe dislocations may result. Structural unemployment and compensation of employees displaced by mandated major changes is a continuing concern. The implication is that a steady and gradual pace of mandated requirements is advantageous in this respect,

This report does not argue that regulation necessarily leads to more economically efficient or commercially desirable allocations of resources. Moreover, regulation may sometimes impose sufficiently high costs and stringent constraints that innovation is impeded. Nevertheless, there are many examples of innovations enabled or enhanced by regulation. When regulation of products and processes is required for health, safety. or other purposes, it was found that potentials often exist for effective and innovative technological solutions, This should be considered in decisions about the timing, form, and implementation of regulatory actions.

Government actions often have unintended effects on innovation, and several programs together may generate unexpected effects.

- Intense pressure for rapid change may force industry to patch up an existing technology rather than risk the failure of a radical innovation. [14]
- Stringent requirements for approval of new products may act to reduce competition from new producers and new entrants in a business, thus increasing the value to firms of established and accepted products.
- At the level of detailed design changes, Federal laws or regulations have been found to act as a constraint to innovations about as frequently as they act to stimulate change. And if regulations are not continually updated to reflect changing possibilities, they may greatly reduce potentials for improvements. [15]
- An implication is that performance specifications would generally distort potential improvements to a lesser extent than would specification of specific technologies or solutions. [16]
- Major innovations have drastically reduced the total costs of ownership and use of major appliances, aircraft engines, and electronic systems, but this was not readily apparent at first. Undue stress on cost improvement might discourage seemingly costly new technologies which have dramatic potential for savings in the longer run. [17]

There is evidently potential for damage as well as benefit in many Government programs and actions that influence technology. In this respect a special note should be made concerning the Federal role in actually performing research and development. The evidence reviewed strongly indicated that large projects directly performed by Government for the development of products and production process equipment have been quickly made obsolete by the rapid pace of innovation in industry, and their results have not found widespread use. This was true of projects to develop compact proximity fuses based on vacuum tubes, of development of equipment for automatic production of transistor-based circuits, of projects to develop several liquid-cooled aircraft engines, and so on. [18] Similar cases are evident in the United Kingdom and Germany. One reason for this appears to be the firms' superior knowledge of critical details of the production process, its interaction with product design, and a multitude of important adjustments in both. Conversely, Government performance of more basic research had evidently made outstanding contributions to industrial innovations. This seems to be true for example, of basic work on aerodynamics, high-temperature liquid cooling, improved aviation fuel, and other areas of general usefulness which, however, do not yield proprietary advantage. [19]

Design of programs and analysis of the effects on innovation of Government programs and actions should recognize that there is no simple connection between cause and effect. Actions

[14] Abernathy and Chakravarthy, 1977. op cit

[15] A H Rubenstein and John EEttlie, "*Analysis of Federal Stimuli to Development of New Technology by Suppliers to Automobile Manufacturers. " *Final Report to U S Department of Transportation,* March 1977

[16] R. O. Schlaifer and S.D. Heron, *Development of Aircraft* Engines *and Fuels* (Cambridge, Mass.: Harvard University Press, 1950).

[17] Utterback and Murphy. 1977, op. cit.

[18] Ibid.

[19] Kim, 1977, op cit

can have multiple effects. Many actions can contribute to the same effect. Several actions can interact to produce a disproportionate effect. The net result or bottom line so to speak is not always clear. For example, early support given to semiconductor technology through development contracts, direct procurement of prototypes and early production at premium prices, dramatization and demonstration of the military need for greater performance and reliability, and a willingness to encourage new and unproven suppliers all promoted entry of new firms. But their relative importance seems to vary widely in the case of different firms. Similarly, reductions in prices for electronic components appear to have been caused by a variety of factors: the development of production lines for "industrial preparedness, " direct and indirect procurement of a high volume of electronics components, encouragement of entry, competition and development of "second sources, " and occasional decreases in purchases by the military. By the same token, manpower development and mobility were also affected by many different actions. 20

No one policy or technique can be recommended as a key to effective stimulation or support for change. Many factors, including availability of private venture capital, can contribute to entry of new firms and enhance the climate for major product innovation. These may be supported by other conditions such as the supply and mobility of key personnel, Government encouragement of competition, and so on. Several factors might be considered as a set of loosely coupled active elements rather than one being cause and the other effect. Lack of balance or a lack of one critical factor may be seen as a "barrier" to innovation.

Finally, sophisticated control of program implementation has apparently enhanced the influence of many Government programs and actions. Should funds be concentrated on one firm or spread among many? Should established firms be supported or should new entrants be encouraged? Should suppliers of advanced components be supported as well as users of such components in final systems or products? Should specifications be based on an informal understanding of best performance or best effort, or should they be rigidly detailed? Should standardization be stressed, or should diverse parallel approaches be taken? Each of these conflicting options, among many others, has been effective in certain examples. Apart from the content of the program, careful timing and implementation can greatly enhance its impact.

1n conclusion, Government programs and actions that affect innovation have widely varying effects in different industry and technology contexts. Timing, interaction with other programs, and the details of implementation are often crucial. This has been well-understood in many successful past developments for national purposes going back from well beyond early encouragement of the radio industry and Government pressure for four-wheel brakes on autos to contemporary examples such as integrated circuitry, numerically controlled machine tools, emission controls, etc. Understanding of the dynamics of different industries is needed in order to promote positive and avoid negative impacts. Similarly, what industry can and should do with respect to innovation can not be judged independently of Government action. Since we are beginning to recognize the many areas in which Government and industry are closely interdependent, Government actions must be designed with a greater appreciation for industrial potential and responses. This will require study of more industries, product areas, and services. We need to understand industry organization, decision-making, and responses with greater generality and subtlety. A program of active experimentation and study in cooperation with industry is needed to provide an environment conducive to more creative technological advance.

[20] Utterback and Murray, 1977, op, cit