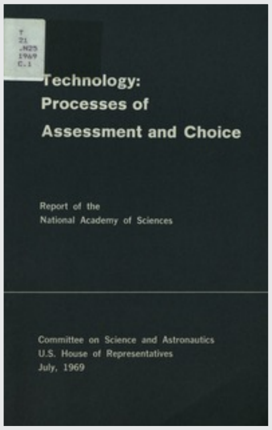

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CONTRIBUTORS

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Report of the
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Committee on Science and Astronautics
U.S. House of Representatives
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Report of the
National Academy of Sciences

COMMITTEE ON SCIENCE AND ASTRONAUTICS
U.S. HOUSE OF REPRESENTATIVES

July 1969

[Committee Print]

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PREFACE

In December 1963 the Committee on Science and Astronautics concluded a formal agreement with the National Academy of Sciences. The purpose of the agreement, which evolved into the first series of contracts between Congress and the Academy, was the production of study and pilot programs designed to isolate and describe some of the critical policy issues which government must consider in its decisions to regulate, support or otherwise foster research in the United States.

This report is the third submitted to Congress under the agreement.

The first study, entitled "Basic Research and National Goals," was submitted in March 1965. The second study, entitled "Applied Science and Technological Progress," was submitted in June 1967. The current study addresses itself to what our committee has identified as one of the most urgent problems pressing upon society today. It is an area in which members of this committee have been working extensively for the past 5 years, and it will be of significant utility, we believe, in leading to effective legislation.

None of these reports has been easy to undertake since each has required the careful evaluation of complex and elusive relationships including those which are constantly evolving between government, science, technology, society and individuals.

In carrying out the terms of the agreement and in developing the form and substance of the report, we in the Congress are particularly indebted to Representative Emilio Q. Daddario who, as chairman of the Subcommittee on Science, Research and Development, served as the congressional agent and focal point throughout, and to Dr. Harvey Brooks who, as Chairman of the Academy's Committee on Science and Public Policy, served in similar fashion on behalf of the Academy.

GEORGE P. MILLER, *Chairman*,
Committee on Science and Astronautics.

NATIONAL ACADEMY OF SCIENCES

OFFICE OF THE PRESIDENT
WASHINGTON, D.C.

July 28, 1969.

Hon. GEORGE P. MILLER,
Chairman, House Science and Astronautics Committee,
Washington, D.C.

DEAR MR. MILLER: I have the honor and privilege of submitting to you the attached report, *Technology: Processes of Assessment and Choice*, prepared by an *ad hoc* panel of the Committee on Science and Public Policy of the National Academy of Sciences. This study was undertaken in response to a request from Representative Emilio Q. Daddario, chairman of the Subcommittee on Science, Research and Development of your committee.

The membership of the Academy joins me in expressing gratitude to the Congress, whose recognition of our Nation's requirements for the development of institutionalized techniques and programs for technological assessment was the stimulus for the deliberations of our panel.

I share with the members of the panel and the Committee on Science and Public Policy the hope that this report will prove useful to the Congress as it deliberates and acts upon the challenges of our impressive technological advance.

Sincerely yours,

PHILIP HANDLER, *President.*

NATIONAL ACADEMY OF SCIENCES

COMMITTEE ON SCIENCE AND PUBLIC POLICY
2101 CONSTITUTION AVENUE
WASHINGTON, D.C. 20418

DR. PHILIP HANDLER,
President, National Academy of Sciences,
Washington, D.C.

DEAR DR. HANDLER: I take pleasure in transmitting to you the final report of the *ad hoc* Panel on Technology Assessment, created by the Committee on Science and Public Policy in response to a request from the House Science and Astronautics Committee. The report represents the consensus of the *ad hoc* panel and has been reviewed by the members of the Committee on Science and Public Policy. The *ad hoc* group, while in agreement with the general philosophy and thrust of the report, has differed in certain matters of detail, especially pertaining to the organization of a possible technology-assessment structure within the federal establishment. The pros and cons of each point of view concerning this are discussed in the report. To illustrate, while there was agreement that the technology-assessment structure should have close ties both to the Congress and to the Executive, there was disagreement as to whether the central responsibility should be tied to the executive or the legislative branch. Similarly, although the report recommends that certain parts of the technology-assessment responsibility rest in both the President's Office of Science and Technology and the National Science Foundation, there were varying degrees of skepticism as to the ability of those agencies, as presently staffed and organized, to fulfill adequately the responsibilities suggested for them.

The *ad hoc* group embarked on its efforts with the idea of a case-study approach, in an effort to see what lessons could be learned from past efforts at technology assessment and from past failures to anticipate the impact of emerging technologies. We hoped to answer the question: If we had it to do over again, how could we do it better? However, we soon found this approach to be impractical. The problems of technological impact are so diverse, and the variety of technologies so great, that it proved impossible to find a reasonable number of cases that could be said to be truly representative of the problem. We did assemble a great deal of case material, varying widely in detail and completeness. This material was used, however, only for background in our discussions, and it was decided not to include it in the report. Instead, we concentrated on the structuring of the problem and on the design of an organizational framework for the technology-assessment function within the federal government.

It must be emphasized that technology assessment in some form and extent is already ubiquitous in American society, most obviously in industry and in government. It lies at the core of all decisionmaking with respect to the generation, application, or regulation of technology and its applications. Thus the panel early rejected the idea of a highly centralized mechanism. The primary purpose of such new mechanisms as might be recommended would be to identify priorities among problems and opportunities of technological impact, and to begin to develop greater breadth and consistency in the criteria and methods used in all the diverse technology assessments going on at all levels of government and in many agencies. In other words, what we saw as needed was an agency, appropriately placed in the federal structure, that could provide leadership in developing a more coherent, consistent, and comprehensive approach to technology assessment throughout government and ultimately in the private sector as well, and that could draw public and scholarly attention to the relevant issues and problems.

In conclusion, I think it is worth remarking how much we enjoyed our assignment. Many members of the *ad hoc* panel began the task with a good deal of skepticism, feeling that the problem was impossibly broad and diffuse, or that the diversity of backgrounds of the participants would make a consensus either impossible or hopelessly platitudinous. As our meetings proceeded, most of this skepticism evaporated and the members approached the task with increasing enthusiasm. We learned a great deal from each other, and found that we could impose an unexpected measure of structure upon the problem. We must all acknowledge a great debt to Representative Daddario, who stimulated us to undertake this effort, and whose vision of the problem turned out to be more realistic than most of us had originally thought.

Sincerely yours,

July, 1969.

HARVEY BROOKS.

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CHAPTER I. INTRODUCTION

Origins of the Report

In recent years concern has mounted over society's seeming inability to channel technological developments in directions that sufficiently respect the broad range of human needs. Whether rightly or wrongly, the belief is now widely held that the continuation of certain technological trends would pose grave dangers for the future of man and indeed that the ill-considered exploitation of technology has already contributed to some of the most urgent of our contemporary problems: the specter of thermonuclear destruction; the tensions of congested cities; the hazards of a polluted and despoiled biosphere; the expanding arsenal of techniques for the surveillance and manipulation of private thought and behavior; the alienation of those who feel excluded from power in an increasingly technical civilization.

Even among those who readily concede that technological advance has, on the whole, been a great boon to mankind, there has emerged a deep strain of skepticism toward proposals and projects that, in an earlier day, might have been hailed as the very symbols of human progress. Whereas a few years ago, for example, the idea of a supersonic transport seemed to many the obvious fulfillment of man's airborne destiny, today some who might once have greeted the SST with unbounded enthusiasm are asking whether it is truly a sign of progress to fly from Watts to Harlem in two hours, vibrating millions of ears and windows in between. Many who once viewed opposition to the interstate highway program as essentially reactionary have begun to wonder whether the convenience of a proposed new expressway to its mobile users will really outweigh its costs to those whose lands and lives it will traverse. Haunted by fears of lead poisoning from automotive exhaust and mind poisoning from televised violence, increasingly influential segments of the population have begun to ask whether we can continue to wait until technology-related problems reach near-critical magnitudes before we renew the search for *ad hoc* solutions.

Some who share these general misgivings tend to make modern technology the scapegoat of all our social ills. They perceive technology as having become an end in itself, subjecting man to its demands rather than serving human needs. They regard it as inherently destructive of personal freedom and fear that it will make the world totally uninhabitable or at least rob it of all hope and beauty. This wholly pessimistic attitude rests, of course, upon a vast oversimplification—as does the converse notion that technology is a universal solvent that, having liberated Western man from the bondage of poverty and disease, need only be applied vigorously to assure global prosperity and universal happiness (*1*).

Between these two extremes lies the view of those who recognize that benefit and injury alike may flow from technology, which, after all, is nothing more than a systematic way of altering the environment. They recognize that the quality of life has been greatly improved by technological advance and would deteriorate rapidly in a period of technological stagnation; that a technological culture, already adopted by one third of the human race and eagerly sought by much of the remaining two thirds, could be abandoned only at the cost of relegating hundreds of millions of human beings to suffering and death. The choice, from this perspective, is not between the abandonment of technology as a tool of human aspiration and the uncontrolled pursuit of technology as though more tools invariably meant a better life. *The choice, rather, is between technological advance that proceeds without adequate consideration of its consequences and technological change that is influenced by a deeper concern for the interaction between man's tools and the human environment in which they do their work.*

For those who hold this more balanced view, the expression "technology assessment" may acceptably describe what occurs when the likely consequences of a technological development are explored and evaluated. Their objective is to improve the quality of such efforts at exploration and evaluation and thereby to foster a more constructive evolution of our technological order. But the concept of improved technology assessment is by no means a unitary one; it suggests different things to different people. The contents and focus of the notion vary with the vital interests and perspectives of its many proponents.

To some, concerned primarily with the *preservation and enhancement of environmental quality*, technology assessment suggests the evaluation of technical changes or applications from the perspective of their likely impact on various environmental goals and resources—or the exploration of how particular environmental objectives might be affected, beneficially or adversely, by the growth and spread of various technologies. Thus we have seen proposals to create, in the Executive Office of the President, a Council of Ecological or Environmental Advisers (*2*) (on the model of the present Council of Economic Advisers) or an inter-agency council on environmental issues, such as the Environmental Quality Council recently established by the President (*3*). We have witnessed proposals to establish ombudsmen to intervene in agency proceedings as spokesmen for en-

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vironmental quality against the incursions of technology (*4*). We have seen proposals to amend the Constitution by asserting the right of the people to a pure environment (*5*). And we have witnessed a proposal to create a Select Senate Committee on Technology and the Human Environment (*6*), to focus public and political attention on the longer-range environmental consequences of technological decisions.

To others, concerned with the *measurement of social change* as a step toward the achievement of broad national goals, technology assessment connotes the use of new tools to monitor the impacts on society of technical changes (among others) and to improve the quality of feedback from social effects to technological (and other) developments. Thus we have witnessed a movement urging the evolution and refinement of "social indicators" to supplement the present body of economic indicators (*7*). We have seen proposals advocating the creation of a Council of Social Advisers (*8*) (again on the model of the present Council of Economic Advisers) and the establishment of an annual Social Report to the President (analogous to the current Economic Report). We have witnessed proposals to create a National Foundation for the Social Sciences (paralleling the National Science Foundation) and to add social and behavioral scientists to the President's Science Advisory Committee (*9*). All these proposals focus concern on the *social* impact of technological change and on relating technical to social goals, although in a broader interpretation social impact often includes the physical and biological environment as it affects the quality of human life.

Yet another group is concerned broadly with the need for *greater foresight and planning* to guide technical change with more timely and comprehensive balancing of total costs against total benefits. To this group, technology assessment means an attempt to project the likely growth and probable impacts of specific technologies—such as weather modification, the supersonic transport, satellite communications, and computer-aided instruction. Thus we have seen the emergence of "technological forecasting" as a fashionable new discipline (*10*) and have heard increased discussion of "early warning systems" to alert planners and the general public to the potentialities and dangers of incipient technological developments and of alternative possibilities. This collection of proposals focuses attention on particular technologies and on foreseeing the variety of social and environmental consequences that might follow from their widespread application.

Another group, concerned with *improving the allocation of public resources*, views technology assessment as a means of identifying and measuring the possible uses of technologies generated by federally supported research and development activities. Of special concern to this group is the supposed transfer of space and defense technology and management techniques to the civilian sector, particularly for the solution of major social problems related to urbanization—such as housing, crime, transportation, and municipal public services. In this connection we have seen proposals to create an Agency for Technological Development (*11*), and have witnessed proposals to strengthen the Office of Science and Technology or otherwise to centralize and rationalize the allocation and management of federal science resources and efforts (*12*). Implicit in this set of proposals is the assumption that the allocation of scientific and technological priorities can serve as the catalyst for new social and political priorities, rather than *vice versa*.

And to still others, whose concerns lie with *better program and policy evaluation* and who do not restrict their attention to resource allocation, technology assessment represents one component of an extended version of planning-programming-budgeting (PPB). Their emphasis is upon developing more precise definitions of program objectives as they relate to national goals and priorities; more specific and unbiased criteria for assessing program potentiality and performance in cost-benefit terms; and more successful ways of modifying old programs or proposing new ones with the help of such analytic devices (*13*). Along these lines, we have seen a proposal to form a standing Citizens' Committee on National Goals and Priorities, with counterpart capacities in the executive and legislative branches (*14*). We have witnessed proposals designed to enhance the capacity of Congress to evaluate the technical components of legislative issues as they relate to broad national objectives (*15*). And we have seen a proposal to establish, at each level of government, an independent "fourth branch" to conduct a continuing objective and "scientific" evaluation of the goals, priorities, and programs of the political branches, using the best modern analytic tools provided by the physical and social sciences (*16*).

Several of these recommendations revolve about axes other than those of science and technology and do not give the assessment of technology *per se* a central role, but virtually all of them reflect some awareness of the fact that the interplay between technology and man's natural and social environments significantly affects the problems and opportunities that most frequently dominate the choices of contemporary life. One of the proposals, in particular, aims squarely at the technology-society interface and asks how the interactions at this interface might be better observed and more wisely managed. This proposal is Representative Daddario's bill to establish a Technology Assessment Board "to provide a method for identifying, assessing, publicizing, and dealing with the implications and effects of applied research and technology" (*17*). The bill speaks of the need for

> . . . identifying the potentials of applied research and technology and promoting ways and means to accomplish their transfer into practical use, and identifying the undesirable by-products and side-effects of such applied research and technology in advance of their crystallization and informing the public of their potential in order that appropriate steps may be taken to eliminate or minimize them.

Representative Daddario introduced the bill, H.R. 6698, early in 1967 "not as a piece of perfected legislation but as a stimulant to discussion (*18*)." His Subcommittee on Science, Research, and Development of the House Committee on Science and Astronautics sponsored a Seminar on Technology Assessment in September 1967 to explore in a preliminary way some of the concerns suggested by H.R. 6698 (*19*). The participants in that seminar differed on matters of detail but agreed broadly that the proposed legislation was directed to a very real problem and also raised subtle questions that required much closer investigation. Accordingly, Congress requested both the National Academy of Sciences and the National Academy of Engineering to undertake studies of technology assessment: what it means to various groups, how it occurs today, how it is related to the behavior of individuals and organizations, how its quality might be improved and its influence enhanced.

This report is the response offered by the National Academy of Sciences to Congress' inquiries. The report, which we view as but one step in what must become a continuing process, represents the culmination of nearly a year of discussions by the Technology Assessment Panel, a group created by the Academy's Committee on Science and Public Policy to consider the need for an improved assessment capacity and the possible ways of achieving it. In undertaking that task, we have not confined our attention to government mechanisms, but have considered also the importance of improving technology-assessment capability and awareness throughout our society.

Although we have given thought to the many overlapping proposals discussed above, all of which bear some relation to technology assessment, we have recognized an obligation to select a particular unifying theme from among the many that are available. In particular, we have focused on technology assessment as the exploration of trends in technological development, working outward toward the effects on society, the environment, and the individual effects of such trends. In an appendix to this report (Appendix A, pgs. 123–135), we discuss other possible foci for technology assessment and we opt for a mixed approach. But in order to keep the problem politically manageable, as well as to avoid an impossible diffusion of effort, we have given primary attention to assessment endeavors that use technology as a starting point, as opposed to analyses that begin with society, the environment, or the individual, and we urge a similar focus for the new institutions whose creation we recommend in Chapter V.

Nature of the Problem

DEFINING THE INQUIRY

Conceived most broadly, any inquiry into the interface between technology and the human habitat may become an inquiry into the entire universe of questions that bear upon the most critical problems of contemporary civilization. To make its task manageable, the panel decided to draw lines dictated by the concerns that led Congress to request this study, by the matters that we think demand the most urgent attention, and by the issues that we feel most competent to address.

At the outset we set aside as beyond the scope of this report those ultimate philosophical issues that seem to be posed by any increasingly technical civilization (*20*). We set aside as well the implications for human values of basic theoretical discoveries in the biomedical or other sciences (*21*). Scientific discovery can indeed have important consequences for the ethical and moral foundations of a society, but our concern here is not with the effects of science—what man knows or hypothesizes about his world—but with the effects of technology—what man can do and chooses to do with what he knows.

At the same time, we have regarded as outside our inquiry any attempt to assess in detail the specific consequences or implications of any particular technological development or set of developments. Our approach has been quite different. *Recognizing that the assessment of technological prospects and perils has become a pervasive activity in a wide variety of private and public institutional settings, we have undertaken to identify what seem to us the most critical deficiencies in existing processes of assessment and decision-making with respect to the evolution of technology in our society.*

As they consider the possibility of exploiting or opposing a technological opportunity or development, individuals, corporations, and public institutions attempt to project the gains and losses to themselves of alternative courses of action, and seek a course designed to maximize the gains while minimizing the losses. The difficulty is that self-interested analyses of this sort may ignore important implications of particular choices for sectors of society other than those represented in the initial decisions. In their pursuit of benefits for themselves or for the particular public they serve, those who make the relevant decisions may fail to exploit technological opportunities that, from a broader perspective, might clearly deserve exploitation. Likewise, as they seek to minimize costs to themselves, the same decision-makers may pursue technological paths that, again from a broader perspective, ought to be redirected so as to reduce undesirable consequences for others. A wide variety of what economists call external costs and benefits thus falls "between the stools of innumerable individual decisions to develop individual technologies for individual purposes without explicit attention to what all these decisions add up to for society as a whole and for people as human beings" (*22*).

In part, this phenomenon is a corollary of the value our society has placed upon relatively unrestrained decision-making by autonomous individuals and institutions. In part, the phenomenon follows from the "tyranny of small decisions" (*23*)—incremental choices that, taken by themselves, may seem unworthy of notice but, taken altogether, may create problems of major proportions. And in part, it is a corollary of the inherent difficulty of predicting and evaluating certain kinds of external costs and benefits, which make themselves felt indirectly or at times and places far removed from the initial points of decision. Indeed, the very difficulty of foreseeing and quantifying such secondary consequences discourages their consideration in decision-making processes and encourages emphasis upon the much more readily predictable and quantifiable primary effects.

None of these considerations, of course, is entirely new. Long before man found himself committed to a highly technological culture, he had learned to make systematic use of a wide variety of tools, or technologies, to achieve a great many ends, and each new tool, as well as each new kind or level of use, brought benefit to some and injury to others. For centuries, a wide range of benefits and injuries were simply ignored in the decision-making processes that influenced technological change. Social institutions were operated primarily for the benefit of small elites, and effects on the great majority of the population seldom came within the purview of decision-making—a situation that prevails in many developing societies even today. Yet the same technologies whose effects we sometimes deplore are themselves largely responsible for the fact that we both can and do consider the effects of decisions and policies on a much larger part of the human population than ever before. Despite the long history of inattention to the wider consequences of technological change, therefore, our panel starts from the conviction that the advances of technology have yielded and still yield benefits that, on the whole, vastly outweigh all the injuries they have caused and continue to cause.

But such advances have also made possible population growth and income expansion, both of which have generated increased demands on resources for consumption and for waste assimilation. Moreover, as the number of people who share in the material benefits of technology has grown, there has developed a mounting sense of individual worth and an escalating set of demands for a better life, a life freer of the harmful side-effects of technological progress. At the same time, advances in science and technology have brought advances in our ability to anticipate the secondary and tertiary consequences of contemplated technological developments and to select those technological paths best suited to the achievement of broad combinations of objectives. The tremendous growth of science and technology during the last two decades has indeed created a situation in which there exist many more technically feasible options than we can possibly choose to pursue, coupled with the sophisticated methods of analysis and forecasting needed to select those options that can minimize unwanted consequences.

This enhanced sensitivity and expanded range of alternatives does not necessarily imply that the deleterious side-effects of technological change are worse today than they were a century or two ago—although some obviously are. It does imply that our visions and capacities have so broadened and deepened that we can now, for the first time in human history, realistically aspire to have it both ways: to maximize our gains while minimizing our losses. The challenge is to discipline technological progress in order to make the most of this vast new opportunity.

Nor can this opportunity be foregone without incurring a considerable risk of grave injury to mankind. For the new power, rapidity, and momentum of technological development; the diminishing lead-time between initial innovation and widespread application; the expanding radii of technological effects in space and time; the increasing size, density, and affluence of the populations in which such effects are felt; and the fact that the environment is rapidly approaching its maximum capacity to assimilate waste—these circumstances have created a situation in which the cumulative and interacting deleterious consequences of many technological developments and decisions might ultimately outweigh their primary benefits. Particularly as it becomes necessary to engage in technological enterprises on a national and even a global scale, the need to project the total systems effects of alternative courses of action will become far more pressing than it was when we could experiment with more localized projects. For all these reasons, we are moving into a period in which the margin for error will be narrower and the costs of unwise choices higher than in the past.

In this context of heightened danger as well as opportunity, decisions concerning the development and application of new technologies must not be allowed to rest solely on their immediate utility to their sponsors and users. Timely consideration must be given to the long-term sacrifices entailed by their use and proliferation, and to potentially injurious effects upon sectors of society and the environment often quite remote from the places of production and application. For by the time such consequences have become so obvious as to generate intense political concern, we may find that the psychological and financial commitments of various individuals or groups to technological paths and institutional arrangements already selected will have made any significant change of direction very costly if not altogether impossible. Thus, we may freeze ourselves into technological patterns whose far-reaching consequences not even their originators would deliberately have chosen. Most of the effects of technological or social shortsightedness that cause concern today—environmental pollution, social dislocation, urban congestion, the highway death toll, noise—may come to seem minor indeed when compared with the problems that could then confront us. Most of the undesired effects of technological change are still reversible, albeit at ever higher costs, by yet further applications of science and technology, or by changes in habits, attitudes, and institutional arrangements. But as these effects become more nearly global in scale, we may increasingly find ourselves faced with consequences that are truly irreversible—for example, profound climatic changes, or permanent alterations in ecological regimes, or irreversible social deterioration.

Seen in this light, the problems to which we must address ourselves are these: *How can we in the United States best begin the awesomely difficult task of altering present evaluative and decision-making processes so that private and public choices bearing on the ways in which technologies develop* *and fit into society will reflect a greater sensitivity to the total systems effects of such choices on the human environment? How can we best increase the likelihood that such decisions (domestically and, in the end, globally) will be informed by more complete understanding of their secondary and tertiary consequences, and will be made on the basis of criteria that take such consequences into account in a timelier and more systematic way? And how can we do these things without denying ourselves the benefits that continuing technological progress has to offer, especially to the less-favored portions of the human population?*

We must note emphatically that the alternative to such heightened sensitivity and broadened criteria is not necessarily a continuation of current rates and modes of technological innovation and diffusion. It is entirely possible that, frightened by the untoward side-effects of technological change and frustrated by their inability to "humanize" its direction, people with much power and little wisdom will lash out against scientific and technological activity in general, attempting to destroy what they find themselves unable to control. That sort of Luddite response would, of course, be tragic, but it may eventuate unless we can take constructive first steps in the general direction discussed here.

As this report explores the need for such steps, it will inevitably emphasize mistakes that have been made in the past—instances when technological developments chosen for exploitation now seem to have been needlessly injurious to some set of social or environmental interests; instances when alternative technologies could have achieved comparable objectives at significantly reduced social cost; instances when technological developments were accompanied by inadequate or inappropriate systems of supporting institutions and technological or legal safeguards. But deploring such undersirable side-effects of technological change is not tantamount to decrying technology itself. Indeed, technology as such is not the subject of this report, much less the subject of this panel's indictment. *Our subject, instead, is human behavior and institutions, and our purpose is not to conceive ways to curb or restrain or otherwise "fix" technology but rather to conceive ways to discover and repair the deficiencies in the processes and institutions by which society puts the tools of science and technology to work.* Thus, if the panel seems in this report "quick to lament the fallen sparrow, but slow to celebrate the fall of 'Typhoid Mary,' (*24*) " the reason is not that we have forgotten the benefits of technology but that we have been directed by Congress to explore how such benefits might be attained with less injury to human and environmental values. Any negative emphasis in this report is thus no more than an inevitable corollary of pursuing our assignment.

The current concern with the undesirable secondary consequences of technology reflects not so much the fact that technology is more threatening today than it has been in the past as the fact that we have perceived our actions to have wider consequences than we earlier contemplated, have learned how to use science and technology to explore and control such consequences, and have become willing to assume responsibility for those consequences "over wider stretches of space and time. In a very basic sense, modern science, by deepening Man's vision of the interconnectedness of things, has greatly enlarged his moral horizons" (*25*). How best to expand our decision-making processes to fulfill those enlarged expectations is the central question to which this report is addressed.

TWO PRELIMINARY DISTINCTIONS

The task confronting us involves a complex set of problems that might usefully be described in the form of a two-dimensional matrix, with the horizontal dimension consisting of technologies and supporting systems, and the vertical dimension consisting of perception and response.

Technologies and Supporting Systems

We must distinguish clearly between *technologies* or *technological systems*—codified ways of deliberately manipulating the environment to achieve some material objective—and the legal and economic arrangements through which such technologies become available and are subjected to social control—arrangements that are here described as *supporting systems*. The automobile and the highway network comprise a technology or a technological system; rules of accident law, automobile insurance schemes, and traffic policemen are components of the corresponding supporting system.

The panel believes that in some cases an injection of the broadened criteria urged here might have led, or might in the future lead, to the selection or encouragement of different technologies or at least modified ones—functional alternatives with lower "social costs" (though not necessarily lower total costs). For example, bioenvironmental rather than primarily chemical devices might have been used to control agricultural pests, or there might have been design alternatives to the purely chemical means of enhancing engine efficiency, or mass transit alternatives to further reliance upon the private automobile.

We believe, however, that in the vast majority of cases an improved set of decision-making processes might have led, or might eventually lead, not to different technologies but rather to different supporting systems. These might include, for example, different ways of allocating radio frequencies or distributing contraceptives; different ways of integrating automobiles into the transportation network, with more rental and less ownership of empty seats; different revenue sources for the television industry; or different ways of compensating and/or relocating persons injured by pollution, declining industries, or highways.

A classic and timely illustration is furnished by the application of advancing technology to traditional agriculture in the developing world. Few would question the primary benefits—indeed, the absolute necessity—of this "green revolution" in Asia and elsewhere, but it is likely to raise massive problems of economic dislocation, social unrest, and political upheaval—unless the developed nations, in cooperation with the third world, plan very carefully (*26*). Intelligent planning and coordination of social, legal, and economic policies with technological trends of unquestioned primary benefit will yield recommendations that are often non-technological in character—recommendations with respect to supporting systems rather than technological systems—but this should not obscure the relevance of such coordination to the enterprise of technology assessment broadly conceived.

Perception and Response

We must distinguish also between changing the *perceptions* of decision-makers and changing their *responses* to what they perceive. With respect to the former, it seems clear that there is a need to develop and organize the capacity and willingness of all relevant decision-makers and institutions (not simply of some central agency) to cooperate in a broad, society-wide (and ultimately global) effort to perceive (monitor, predict, understand, evaluate) more sharply than in the past the full range of consequences of technological developments—*at sufficiently early stages to make a difference and in terms of sufficiently broad yet measurable criteria to overcome the bias* *toward technologies and supporting systems that promise immediate utility to those for whom they are designed.*

But changes in perception alone, however profound, are almost certain to prove insufficient. The relationship of knowledge to action is exceedingly subtle and complex; to alter the conduct of those who sponsor technological developments so that their behavior in fact reflects broader perceptions (i.e., so that they are guided by new criteria) might require changing the legal rules constraining or facilitating conduct; or the incentives, positive or negative, indirectly molding it; or the general attitudes that condition patterns of thought and action.

For virtually every deleterious environmental effect, one could undoubtedly identify many experts who warned us, but for one reason or another their warnings were not heeded. Perhaps their evidence was spotty or inconclusive. Perhaps they assumed that the marshaling of a persuasive case was somebody else's responsibility. Very likely their opinions were not accepted by other experts, or they did not know how to attract the attention of people who could influence the crucial decisions. Perhaps the experts who foresaw the unfortunate effects of particular lines of development were not aware of viable alternatives and so could not convince decision-makers that the rather speculative side-effects they perceived warranted foregoing the tangible and indisputable benefits of particular proposals. Or perhaps the decision-makers simply believed, relative to the values then prevalent, that they had more to lose by heeding the warnings of potential injury than they had to gain by proceeding in disregard of them. In none of these situations would clearer vision alone have sufficed; early warnings were indeed sounded but fell on deaf ears; the need was less for improved perception than for improved response.

Whatever any process of assessment might reveal, choices between alternative technologies or supporting systems are essentially economic and political in character; responses to assessment almost always require that decisions be made between competing and conflicting interests and values. Although one might imagine an authoritative assessment structure designed to circumvent market and political modes of accommodating and resolving such conflicts, the price of such a structure, in terms of its impact upon the basic institutional fabric of our society, would be intolerably high. Whatever improvements might be made in assessment systems, therefore, it is important to remember that the products of such systems ultimately represent no more than inputs into the complex network of decision-making processes, private and public, economic and political, that together mold the growth of technology and channel its integration into the social structure.

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CHAPTER II. EXISTING PROCESSES OF ASSESSMENT AND DECISION

As we proceed to the body of the report, we make two preliminary observations about the relevance—and the irrelevance—of history. Hindsight alone plainly will not suffice. The panel initially considered but ultimately rejected the notion of building its report around a set of historical case studies. Had we attempted to do so, we should have been forced to identify a set of examples sufficiently representative to suggest how a successful system of assessment and response ought to be structured. But one cannot know definitively how representative a selection one has made unless one knows in advance precisely how the assessment process ought to operate. The most that can be achieved through the "case study" method is a rough approximation—one that must be supplemented by exploration of the relevant institutional and organizational considerations. Morever, we are witnessing a shift in values from those of a basically selfish society to those of a society in which "the public interest" is becoming a matter of more than rhetorical concern. Finally, political and technical decisions now tend increasingly to generate complex chains of interacting consequences that go beyond the immediate objectives of those decisions. These circumstances impose serious limits on the relevance of historical materials and, at the very least, require that they be used with special caution, and that their use be tempered with particular imagination.

But history does have its lessons, and offers us innumerable potentially useful hypotheses. As we have noted previously, our problem, despite its new dimensions is an old one. Men have long invested their resources and energies in the purposeful alteration of their natural and social environments, and thoughtful men have long recognized that such investments in technology, whatever their benefits, may also yield unforeseen and unwanted consequences—from the erosion of the soil to the erosion of the human spirit. Particularly since the panel's objective is to evaluate the possibilities of building on and redesigning existing systems rather than to seek ways of beginning completely anew, we need understanding of how existing systems function, and of how they have either succeeded or failed in the past. We turn then to an examination of those systems.

With the development and expansion of capitalism, there emerged a market structure capable of directing innovative abilities in a systematic way to such areas as production, transportation, and communication. For the most part, the initiation and diffusion of technological changes were governed by this economic market. Some attention, to be sure, was given to anticipated impacts upon military potential or national pride, but investments in research and development, in translation from laboratory investigation to product or process, and in widespread application, were most often determined by assessments of short-range commercial profitability or of broad economic benefits to producers (as in the case of agricultural or mining research).

The resulting tendency to associate private enterprise and the price system with technological innovation and diffusion has occasionally obscured the importance of government in channeling the direction and molding the character of these processes. As early as the Civil War, American naval vessels were used in the initial effort to lay the first transatlantic telegraph cable, nominally a private enterprise. Indeed, the federal government involved itself even earlier in the development of technology—usually in a stimulative capacity, as through the patent system initiated in the late eighteenth century, but occasionally also in a restrictive capacity, as through the regulation of steam boilers initiated in the mid-nineteenth century. Contributing to the frequent failure to discern the government's early role was the fact that, when government intervened in the interest of innovation—as in the extension of railroads across the American continent—it ordinarily did so by enhancing the market rewards of private innovators—for example, through the issuance of patents or the granting of public lands.

By the mid-twentieth century, largely as a result of the massive federal support of research and development stimulated by World War II, government policy had become at least as influential as the forces of the ordinary market in setting the environment for technological change. Today the government finances nearly 50 percent of industrial research and development and virtually every governmental agency is involved in one or more programs designed to further the development and use of some technology, by providing an outlet for its goods and services, or by stimulating it at its inception, or both.

The federal government now exerts a pervasive influence on the development of technology through support for highway construction; water-resource development programs; subsidies for airport construction; management of air traffic control; promulgation of safety regulations in hundreds of industries; extension of tax credits for capital investment and depletion allowances for underground mineral resources; agricultural price supports and the soil-conservation program; aid to education programs that acquire audio-visual equipment; patent and licensing policies; and in countless other ways.

Numerous agencies have been created either to regulate the activities of technology-based industries or clusters of industries (railroads, communication, aviation, electric power, drugs, and others) or to perform rather specialized functions with respect to the impact of technology upon particular facets of the environment. Among these are the Interstate Commerce Commission; the Federal Communications Commission; the Federal Aviation Agency; the Federal Power Commission; the Federal Water Pollution Control Administration in the Interior Department; the National Air Pollution Control Administration and the Environmental Control Administration in the Department of Health, Education, and Welfare; the Environmental Impact Office of the Department of Transportation; the Federal Trade Commission and the Bureau of Standards in their consumer-protection activities; the Food and Drug Administration in its regulation of new drugs and therapeutic devices; and the Atomic Energy Commission in its joint roles of development and regulation.

Decisions on budget allocations for technology wholly or predominantly dependent upon the federal government—whether to go forward with the development of a sea-water desalting plant or with a project like Plowshare; whether or not to proceed with the supersonic transport; whether to open a sea-level Panama canal; whether or not to develop a nuclear-powered merchant marine; which new energy source or conversion method to push (shale oil, direct conversion, or coal liquefaction, for example)—have a profound impact upon technological change in the private as well as the public sector. Federal decisions to develop space and defense technology, for example, have accelerated technological change in industries with important civilian impact, such as computers, integrated circuits, civil aviation, radar, and satellite communications. Similarly, the introduction of Medicare by the government as an organizational advance in medicine will have a profound impact on the development of new technology for medical-care delivery—for example, the use of computers for record-keeping and diagnosis, or the automation of medical laboratory procedures.

The decision-making apparatus of the government has thus come to play a central role in supplementing—and sometimes replacing—the forces of the market as the determinant of the rates and directions of technological change and application in the private and public sectors. This apparatus includes a large number of mission-oriented governmental bodies, whose missions are the advancement or regulation (and sometimes both) of specific categories of technology-related enterprises or effects, and the use of public funds (channeled through grants, contracts, or tax benefits) to support research, development, procurement, and operations.

Within this set of governmental and market processes, the initial assessment of the costs and benefits of alternative technological possibilities is ordinarily undertaken by, or at the behest of, those who seek to exploit one of the possibilities in question for their own purposes. Those purposes may be the enhancement of medium-term return on investment and corporate stability and growth, in the case of private enterprise, or the maximization of benefits to particular constituencies, coupled with bureaucratic survival and expansion vis-a-vis other organizations or governments, in the case of public entities.

To some extent the professional societies are influential in technological assessment—as they were, for example, in the development of the boiler codes. Voluntary industry-wide cooperation on specifications, as in the case of the American Society for Testing and Materials, represents another assessment prototype. Yet such professional groups, however conscientious, often have unconscious commitments to the technology or technologies with which they are associated and tend, with few exceptions, to make little difference in the basic perspectives from which assessments are currently made.

Even when the proponents of a technology (whether in the government or in the private sector) seek financial support from public revenues, their own assessments still provide the basic inputs into the political system. Those inputs may then be supplemented by the views of those organized groups that perceive themselves, or a set of values (such as conservation) to which they are passionately attached, to be prospectively benefited or seriously threatened by the technological change in question. Only the contending interests of those who already recognize their stake in the technology and are prepared to enter the public arena to defend their position find their way into the legislative and appropriations processes. *In all but a few special situations, no other assessment occurs in the initial stages of technological development, when alternative possibilities are being explored, or of technological application, when early performance is being evaluated.*

Of course, even this kind of assessment, which values each technological development solely in terms of its likely impact upon a fairly narrow set of objectives and interests, takes place within a social and legal environment that structures the assessment process in important ways. Institutions like property and contract, supplemented by bodies of rules and incentives of many kinds (as expressed through principles of tort liability, tax law, patent law, copyright law, antitrust law, zoning law, and so forth), and occasionally buttressed by principles of professional ethics (especially in the health field), determine the outer boundaries of what is permissible, and establish, within those boundaries, at least some of the categories of costs and benefits that even the most narrowly self-interested assessment would have to take into account.

Partly as a result of government regulation, partly as a result of public criticism and the consequent fear of ever stricter controls, and partly as a result of a complex set of social trends affecting the fundamental attitudes and aspirations of corporate management, the cost-benefit calculations made within the industrial "techno-structure" have tended in recent years to give greater weight to the secondary and tertiary consequences of investment decisions and management policies. *Rarely, however, has the social and legal context within which assessments are made fundamentally altered the relatively narrow frame of reference for evaluation. With few exceptions, the central question asked of a technology is what it would do (or is doing) to the economic or institutional interests of those who are deciding whether or how to exploit it.*

As a technology is applied widely enough to make its impact felt upon other groups, those groups are theoretically free to strike bargains with its sponsors in order to induce them, for a price, to abandon or alter their activities in directions more favorable to their interests. The many obvious difficulties of entering into such multiple agreements, however, ordinarily rule out this potential mode of adjustment. Only when the deleterious impact of a development upon remote groups or interests is sufficiently severe to generate sustained and organized opposition through legal, political, or diplomatic channels can that impact create any negative feedback (through litigation, regulatory legislation, treaty, or otherwise) to the decision-making processes responsible for the disputed development. Even then, the influence of such delayed feedback is significantly limited by the combined power of all who have come to see their interests as dependent upon the *status quo*.

The assessment and decisional systems thus far described comprise the bulk of the evaluative and directive processes molding the evolution of technology in our society. A more complete description would require mention of the fact that, in a few exceptional areas, continuing assessments are undertaken by one or more agencies empowered to prevent the implementation of a technological proposal or to require a previously approved proposal to be abandoned. In one case—nuclear reactors—this clearance authority is reposed in the Atomic Energy Commission, the same agency that has the mission of advancing the underlying technology. In another case—new drugs—the clearance authority is lodged in the Food and Drug Administration and is not linked to any promotional activity. In both instances, the terms of reference for the assessment are quite narrowly circumscribed: new drug assessments are concerned solely with safety and therapeutic efficacy under described conditions of use; nuclear-reactor assessments are concerned only with control of the hazards to human health and safety posed by radiation and explosions—that is, those features that most spectacularly distinguish nuclear reactors from conventional ways of generating electricity.

A number of agencies, organizations, and individuals conduct *ad hoc* assessments of the effects of those technological developments that have already generated particularly acute concern, and others conduct similar studies of currently significant problem areas (threats to privacy, highway safety, air pollution, and so on) to which well-established or emerging technologies are believed to contribute. *But no mechanism eixsts to trigger such studies in a systematic way at early stages in the process of development and diffusion; to explore means of deciding* *whether a given set of events does indeed represent an "early stage" in a significant technological trend; to examine the terms of reference or the methodologies of such studies as are being undertaken; or to inject the results of such studies systematically into the decision-making process itself.* When Presidential Task Forces, private foundations, or groups like the President's Office of Science and Technology or the President's Science Advisory Committee become involved in efforts of this kind, the usual reason is that a specific area of concern has already reached near-crisis proportions or has otherwise captured the imagination of particularly articulate individuals (Ralph Nader and Rachel Carson come immediately to mind) or of unusually influential groups. The result is often a report that duplicates other efforts, or overlooks important considerations, or comes too late to exert any significant influence on the underlying technology, or is without a recipient other than the public at large.

CHAPTER III. FORMULATION OF OBJECTIVES

In the introductory chapter of this report, we spoke in terms of "problems" and "needs." Implicit in our use of such terms and in much of the literature in this general field are a number of assumptions about how decisions with respect to technological change ought ideally to be made. It seems appropriate at this point to make those assumptions as explicit as possible and to elaborate the sorts of considerations that might be relevant to their evaluation.

The General Welfare

Pervading most discussions of the problems we are considering are terms like "the general welfare" or "the public interest" or "net benefit to society as a whole." One hears it said, for example, that a certain technological development is contrary to "the public interest," or that technological change should be made more responsive to criteria reflecting "the general welfare," or that alternative technologies should be selected according to which will maximize the "net gain to society." Such phrases, of course, have the merit of brevity and the appearance of objectivity, but it is far from clear that they convey any operationally useful meaning.

Almost without exception, technological developments will affect some people or interests adversely and others beneficially, and there simply is no agreed-upon algebra by which one can neatly subtract the pains from the pleasures in order to arrive at a net index of social desirability (*27*). How are the interests of suburban commuters and central city residents to be balanced in the evaluation of urban transport systems? How should the future needs of radio-astronomy be weighed against the present uses of television in allocating the electromagnetic spectrum? How are the desires of conservationists and the "aesthetic minority" to be balanced against the economic needs of local industry? As in any problem calling for evaluation of a proposed resource allocation or distribution, the assessment of a contemplated technological development raises vexing issues of welfare economics, political theory, and ethics. Economists, philosophers, and lawyers have debated these matters among themselves and with one another for generations. Surely it would be unrealistic to suppose that this report could somehow resolve them.

Perhaps the most that the panel can hope to do here is raise a warning against the loose assumptions that have generally characterized discussions of our problem—the assumption, for example, that one can speak intelligibly and unambiguously about maximizing aggregate welfare, or the assumption that measures that are "inefficient" (presumably in the economic sense that the amounts that prospective gainers would pay to secure their adoption fall short of the amounts that prospective losers would demand as the price of their voluntary acquiescence) are, or should be, perceived as ethically "wrong." When progressive taxation or public housing is favored, for example, it is not because these are believed to entail an efficient use of available resources but because they redistribute those resources in ways approved largely for other reasons. It cannot be assumed, therefore, that a technological change that costs those whom it injures more than anyone would be willing to pay for its benefits should for that reason automatically be opposed by public-spirited citizens.

The fact is that, with respect to major technological applications, we lack criteria to guide the choice between efficient resource allocation, ordinarily achieved best through some form of market mechanism (improved as necessary to compensate for external costs and benefits), and other objectives, usually achievable only through non-market mechanisms for expressing value preferences. Because we have a great many values other than economic efficiency, and no transactions in them that confront buyers and sellers, the idea of attempting to compute "net social benefits and costs" makes sense only as a very rough first approach. Ordinarily involved is a complex transfer of welfare from one group to another, or perhaps from one country to another, or even from one time to another—and we evaluate the desirability of such a transfer through various institutionalized forms of collective judgment—political, judicial, or economic.

It would, of course, be desirable to have doctrinal guidelines for how such welfare transfers, or utility trade-offs, ought ideally to be judged for various purposes. Much work is now under way to find surrogates for prices established in markets in specific situations—indicators that suggest the value imputed by society to a given action or avoidance of action. But pending the development of such guidelines or techniques, the most general statement one can confidently make, it seems, is that *technological changes, like other alterations in complex systems, ought not to be made in ways that subordinate every other consideration to the dominant purpose of the immediate project. Some attempt ought to be made to analyze the impact of the project on the full range of other values and interests, and such an analysis should play some role in the determination of whether and how to undertake the project in the first instance.* If a proposed highway would destroy jobs or wilderness or displace people or homes, for example, these detrimental consequences should be considered in deciding whether to build the highway at all and, if that decision is affirmative, where to put it. Precisely how much weight such consequences should ideally be given in the ultimate decision—how a balance should be struck between costs to some groups and benefits to others—must remain a subject for continuing discussion and research. But it is clear that consequences of this sort deserve *some* weight—more weight, certainly, than they customarily receive. As one observer has expressed it, "ways must be found to move toward a concept of multi-purpose planning that recognizes the full spectrum of human needs," (*28*) and away from the single-purpose planning that disregards all but its own narrowly defined objectives. What is needed, in short, is to replace tunnel vision with a more holistic view.

The Preservation of Options

In part because we possess no precise calculus of current costs and benefits; in part because future alternatives, needs, and values cannot be known with certainty; and in part because flexibility is among the most widely shared goals, a basic principle of decision-making should be to maintain the greatest practicable latitude for future action. Other things being equal, those technological projects or developments should be favored that leave maximum room for maneuver in the future. The reversibility of an action should thus be counted as a major benefit; its irreversibility, a major cost.

Policy-making should thus reflect the fact, for example, that pollution of a lake is more difficult to reverse than pollution of a river; or that disposal of municipal wastes in streams and rivers may create an overload that is harder to reverse than may disposal on land. The recycling of wastes, which has only begun to be considered on a broad scale, provides a major opportunity for lowering the irreversibility of the disposal process. The construction of dams and reservoirs, which eventually fill up with silt and hence have a finite life, forecloses the possible use of the same sites for water works when water works may be more urgently needed. This is not to say, of course, that dams should not be built. It is to say, however, that in deciding whether, where, and when to build them, the reduction of future options ought to be explicitly regarded as one of the costs incurred by a decision to go ahead. Although this report obviously cannot propose precise ways of ascribing a quantitative value to the preservation of options, it can stress the importance of continued research as the basis for reasonable attributions of value to future opportunity and the need for continued effort aimed at enhancing the weight of future concerns in cost-benefit calculations.

In a less affluent and technologically sophisticated society than ours, it is occasionally necessary to discount the future rather heavily in order simply to survive in the present. But we in the United States, at least, are under no such compulsion. Because we can afford to pay more attention to tomorrow, we have an obligation to think beyond today.

The Burden of Uncertainty

In any situation of imperfect knowledge, when the consequences of a contemplated action can only be surmised and when its costs and benefits cannot confidently be reduced to a net quantity, it becomes critical to decide where the burden of such uncertainties should fall. Historically, that burden has tended to fall on those who challenge the wisdom of an on-going technological trend. The working presumption has been that such a trend ought to be continued so long as it can be expected to yield a profit for those who have chosen to exploit it, and that any deleterious consequences that might ensue will either be manageable or will in any event not be serious enough to warrant a deliberate decision to interfere with technological momentum. So it was, for example, that drilling rights were leased to oil companies operating in the Santa Barbara channel without sufficient consideration of the possible effects of massive oil leakage near the coast and with inadequate preventive measures to minimize such dangers; that vast quantities of chemicals have routinely been released into the biosphere with little or no timely attention to their potential hazards; that the number of internal-combustion automobiles has been permitted to mount steadily with only sporadic and poorly funded efforts to study alternatives involving mass transit, steam-driven vehicles, or electric batteries; or that repeated decisions have been made to proceed with the development of a supersonic transport, continually relegating to later research the issues of sonic boom and engine noise at take-off.

Why should this be so? Are there not many areas in which the prevailing assumption that the technological *status quo* can safely be permitted to continue or expand is unwise and should be altered? Should there not be some limits on the extent to which *any* major technology is allowed to proliferate (or, conversely, to stagnate) without the gathering of fairly definite evidence, either by the developers themselves or by some public agency, as to the character and extent of possible harmful effects and the relative merits or dangers of various technological alternatives? The panel believes that there should be such limits, and that their establishment is one of the most important items on the political agenda. Society simply cannot afford to assume that the harmful consequences of prevalent technological trends will be negligible or will prove readily correctable when they appear; waiting until deleterious effects become evident entails too high a risk that vested interests—among both producers and consumers—will by then have become so entrenched as to make it politically very difficult or economically very costly to suppress or modify an offending technology or to develop an alternative one.

Our experience with certain pesticides, for example, suggests that carefully designed experiments in the early days of introduction might have substantially influenced the course of technological evolution before we were so thoroughly committed to particular forms of pest control as to make significant alteration extremely difficult. As matters now stand, the widespread dissemination of chemical pesticides, which has undoubtedly prevented countless deaths from malaria, cholera, typhus, and starvation, has also inflicted unintended but widespread losses of fish and wildlife and is increasingly suspected of direct injury to man. The key word is "suspected." There are growing reasons to *suspect* carcinogenic effects, complex interactions in the human system with sex hormones and barbiturates, and even long-term genetic damage—but there is little or no positive *proof* one way or the other. Very little is known about individual idiosyncrasies in human reaction to pesticides or about synergistic effects involving drugs and food additives. To extrapolate reliably from experiments with animals is virtually impossible; and to obtain definitive evidence regarding human effects is extremely difficult. Empirical research in this area seems all but hopeless; the only possibility of accurately forecasting long-term effects in humans appears to lie in investigating and understanding the underlying biochemical mechanisms—calling for fundamental research that has not been undertaken.

The result is something of a dilemma: To prohibit each proposed pesticide use until its benefits are demonstrated to outweigh its suspected dangers would prove

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extremely costly even if it were politically possible; but to permit continued and proliferating uses until their dangers are convincingly shown to outweigh their benefits is to take some rather frightening chances with man's future. It is probably not too late even now to seek safer alternatives through research, but how much easier it would have been if someone had undertaken the burden of such research a quarter of a century ago. Now that knowledge has advanced so far that one can study, in anticipation, at least some of the ecological effects of constructing another Aswan Dam or of opening a sea-level canal; or the effects of paving and housing upon the reflectivity of developed regions of the earth's surface; or the effects of high-altitude aircraft exhaust upon the radiation of the atmosphere; or the broad systems effects of other massive alterations of our natural or social surroundings, the panel believes that there is an obligation to undertake the necessary research and monitoring at the earliest possible stages in the developmental process. But the difficulty of identifying those stages and then of undertaking the needed studies should not be underestimated. The scientific and technical uncertainties in assessment are often not understood by laymen, and it is too easy to mistake tentative professional judgment for scientific fact.

Generating the needed efforts will at least require attempts to sensitize developers themselves to secondary consequences so as to encourage them to invest in the necessary research and monitoring activities. In this connection, it will become vital to decide how to allocate the costs of such research and the costs of developing functional alternatives to minimize deleterious consequences or to maximize desired ones. In what situations, for example, will it be reasonable to impose the full costs of such activities upon the developer, permitting him to recover such costs through higher prices to users and relying on income and welfare policy to serve such social objectives as might otherwise be frustrated by the resulting price increases? In what situations will it be reasonable instead to cover part or all of the increased costs through public investment in the needed research and development? The first solution is that of the Food and Drug Administration; the second, that of the Atomic Energy Commission. The panel believes that far more thought must be given to such issues.

It may well be that, in particular cases, sensitizing developers to deleterious side-effects will not suffice—that, in some areas, it may prove necessary either to extend public funds to stimulate specific alternatives that are deemed preferable to the technological trends supported by the private sector or, conversely, to extend precise regulatory authority in such a way that particular technological applications cannot be widely introduced in the private sector until their advocates have successfully demonstrated to an appropriate governmental institution that only acceptably low damage will ensue. Indeed, in several areas—most importantly, drugs and nuclear reactors—Congress has either subsidized new technologies or has resolved that certain kinds of deleterious consequences cannot be relegated to the category of uncertain "side-effects," but must be thoroughly assessed in advance. With respect to such effects, Congress has decided that the proponent of the responsible technology must persuade an appropriate agency at the outset that certain categories of hazards associated with the undertaking fall within limits determined by Congress or the agency.

But the extension of government subsidy or of regulatory authority in such directions should never, we submit, be undertaken lightly. The panel does not, for example, favor any proposal that would routinely impose upon each manufacturer or producer the burden of proving to some public agency's satisfaction that every new technological application he contemplates will meet a prescribed standard of social or environmental "harmlessness." Any such scheme would ignore a major unfortunate prospect—new and socially desirable technologies lying fallow because of an excessive presumption in favor of the *status quo*—and would necessarily be based on the untenable notion that there exists some objective measure by which a sufficiently wise organization can assess the net social utility or toxicity of a given proposal (*29*). Moreover, any such scheme would entail what the panel regards as a premature rejection of the system of markets, prices, and private enterprise. The many faults of that system should not be allowed to obscure its virtues, and any plan devised to improve our management of technological change should "make maximum feasible use of this ingenious mechanism for allocating resources and calculating effects" (*30*).

Whenever it is possible, therefore, to induce the promoter of technology himself to anticipate and reduce deleterious consequences while seeking out and maximizing socially useful applications, such a course is vastly preferable to one that either harnesses his energies and resources to the achievement of a governmentally prescribed technological plan or compels him to submit the products of his innovative activity to prior clearance by a governmental agency. No mechanism can fully compensate for the delays, the bias, and the rigidity that invariably accompany the creation of a governmental bureaucracy devoted to the furtherance or policing of a given technology.

How the uncertainties inherent in any major new area of technological development should be resolved; what sorts of anticipatory research should be undertaken and how such research should be financed; whether public support should be extended or pre-clearance authority established in a particular area; whether the operation of the free market should be modified less drastically, or perhaps not at all—questions such as these ought to be resolved openly and deliberately by the political process. They should not be resolved by habit or inadvertence, whether in favor of a new technology or against it.

The Creation of Constituencies

One might review much of what has been said here as reflecting a paucity of constituencies potent enough to inject diffuse and poorly articulated interests into current decision-making processes. So, for example, with respect to the "general welfare," the failure of existing processes to give adequate weight to "the full spectrum of human needs" can be seen as the absence of sufficiently influential spokesmen for all segments of society or the environment that might be adversely affected by a given project—particularly those that might be affected in large numbers but only tangentially or imperceptibly. Or, with respect to the preservation of options, the failure to assign sufficient cost to the foreclosing of opportunities can be ascribed to how difficult it is for organized voices speaking for the future to penetrate the decision-making process continuously, comprehensively, and systematically. Finally, with respect to the burden of uncertainty, the habitual tendency to presume technological trends harmless until proven otherwise can be explained by the absence of any group or institution whose function it is to marshal the strongest possible case against a particular trend before it has become enveloped by massive vested interest or political or psychological commitment.

Once the matter is thus perceived, it will readily be seen that the problem involves more than the momentum of the *status quo* favoring a proposed technological application. It also involves the many cases in which the alignment of constituencies and vested interests is ranged against a contemplated technological innovation or application. When a new and more flexible teaching device would threaten existing patterns of bureaucratic behavior, for example, one can usually count on the opposition of certain school officials, but not on organized advocacy by parents and children. When a new and less costly building technique would disrupt the construction industry, one can rely on the opposition of those building interests that would be disadvantaged, but not on organized advocacy by residents of the ghetto who might benefit from cheaper housing. In these and similar situations, a thorough consideration of the relative merits of alternative technologies is rendered difficult if not impossible by the presence of powerful spokesmen for the old technologies, and the absence of effective spokesmen for the new.

Thus the problem is not always the weakness of the anti-technological forces. Although such forces are often much too weak, they are sometimes far too strong. The history of the Bodega Bay controversy in California, or of the Storm King project on the Hudson River, or of the federal highway imbroglio in San Francisco and New Orleans clearly shows that conservationists and city dwellers can make themselves powerfully heard in opposition to technological projects that obviously and immediately threaten their interests or values. The difficult cases are those in which the threat is less pressing and tangible—those that lack a clear focus of introduction and affect large, loosely organized groups too remotely or too weakly to overcome widespread apathy and to galvanize opposition. In these circumstances, the need is not so much for *conflict resolution* as for *conflict inspiration*.

If one could have some assurance that all the potential losers as well as all the potential beneficiaries were adequately represented even in such situations, there would be less reason to fear that decisions would be made on a plainly too-limited basis. Indeed, the very essence of the panel's concern about the narrowness of the criteria that currently dominate technological choices is a conviction that *the present system fails to give all affected interests effective representation in the crucial processes of decision.* It is premature to discuss here the institutional arrangements through which such representation might be secured, but it is not too early to note that securing it ought to be a central aim of policy with respect to technological development.

The Achievement of Consistency

Consistency in the content and application of policy is a basic requirement. The costs of overcoming uncertainties with respect to deleterious side-effects and the costs of avoiding or alleviating such effects, for example, ought to be allocated in such a way that similar postures are assumed with respect to competing activities. To give one illustration, if we adopt safety standards with respect to the exploitation of oil resources significantly less rigid than our standards for the exploitation of nuclear-energy sources, we might arbitrarily bias investment away from nuclear power and accelerate environmental pollution by conventional plants, or unwittingly encourage accidents such as the recent leaking of oil into the Santa Barbara channel. More generally, there is a danger that investment will be shifted away from those selected activities that are compelled to bear more than the usual share of the costs of evaluating and minimizing deleterious side-effects, resulting in fortuitous and often unwise allocations of resources that do not reflect real cost differentials.

Similarly, if a segment of the environment—the sea, for instance—is subject to particularly lax quality standards with respect to technological exploitation of its assimilative capacity, the underprotected environmental segment tends naturally to be treated as a prime dumping ground. So, too, standards that differ from one geographical region to another may generate shifts in industrial location that are, from other perspectives, undesirable or inappropriate.

Such considerations do not argue for standards and criteria that fail to reflect differences among various geographical, environmental, or technological areas. They *do* argue—and strongly—against *accidental* variations and in favor of a viewpoint that stresses the importance of conducting and enforcing technology assessment on a consistent basis.

CHAPTER IV. PROBLEMS AND PITFALLS

Having formulated the panel's basic objectives, we seek now to identify and analyze the major obstacles to their achievement. The analysis will be clarified at the outset by drawing a distinction between *conceptual* and *institutional* limitations upon the ability of any set of assessment-decision processes to attain the objectives set forth in Chapter III. It will be noted, as both sets of limitations are considered, that this distinction cuts across the technology-supporting system and perception-response dichotomies discussed in Chapter I.

Conceptual Constraints

SHORTCOMINGS OF MODES OF ANALYSIS

As the discussion in Chapter III suggests, much work is needed to refine our ways of thinking about the central theoretical problems in technology assessment: how to evaluate and balance conflicting interests; how to ascribe semi-quantitative worth to such elusive goals as the preservation of future choice; how to allocate, between the innovator and his opponents, the burdens of uncertainty with respect to harmful effects; how to divide, between the beneficiaries of an innovation and the rest of the public, the costs of evaluating and overcoming such effects; how to assess and strengthen the adequacy of the representation accorded potentially affected individuals and groups while assuring that inadequate or incomplete technical information, or misperceptions of the situation by affected groups, do not unduly influence final outcomes; how to measure and enhance the consistency with which technology assessment is conducted and enforced. Viewed in part as an effort to identify the sorts of questions that can usefully be asked about technology assessment—those enumerated above, for example—this report is but a small step in the evolution of an urgently needed conceptual base for the assessment enterprise.

FAILURES OF IMAGINATION

Technology assessment, like every intellectual enterprise, tends to be bounded by contemporary assumptions, habitual patterns of thought, and the difficulty of making more than first-order extrapolations. Particularly when an emerging technology appears to represent a merely incremental advance over its antecedents, as was the case when the automobile was still perceived as a "horseless carriage," old habits of thought are projected into areas in which they may prove dangerously misleading. Paradoxically, the demands on creative imagination may be least severe when the technology in question poses an obviously radical departure from precedent.

Even the most open-minded approach, however, cannot guarantee that an assessment will ask the right questions or suggest helpful answers. It is extremely difficult, for instance, to foresee the convergence of several technological developments or of one such development with other trends. Insecticide residues, for example, can stimulate the liver to produce abnormally high levels of certain enzymes, which may then render a number of drugs ineffective at normal dosages (*31*). Various sources of sensory overload may combine to yield unexpected levels of anxiety. Transportation and construction technologies in the cities may collide with production technologies on the farm to aggravate urban unemployment. It is obviously of great importance, therefore, to devote special attention to the potential convergence of various technologies with one another or with related social trends.

This is not to suggest that an appropriate exercise of imagination, coupled with a healthy dose of political wisdom, would have made it easy long ago to disentangle and to deal with the converging technological components of something so complex as the urban crisis. But it might at least have made the crisis somewhat more manageable. It is generally conceded, for example, that the drift to the suburbs has contributed significantly to current urban problems. The many technological amenities that made suburban life more attractive—better communications; the automobile; automatic heating systems; the household refrigerator, freezer, and washer; power equipment for individual lawn care and snow removal—have all contributed to the exodus to suburbia and hence to the problems of the central cities. To be sure, the technological advances making such suburban amenities possible cannot themselves be "blamed" in any meaningful way for the large social changes of which they have become a part. Thus, even if influential individuals could have known some decades ago precisely how these technologies would converge—and how they would interact with technological trends in agriculture and in transportation, contributing to the migration of the rural poor to the cities—they could hardly have responded with remedies directed at the contributing technological trends themselves. But they might at least have recognized sooner than they did the prospects of a major population shift. And they might have understood that, in light of the cumulative effects of emerging technological tendencies, certain social policies required serious re-examination—social policies such as local control of welfare and education, a free market in land, housing-finance schemes favoring single-family suburban dwellings, minimum-wage laws, and governmental passivity with respect to housing and job discrimination.

Almost as difficult as conceiving of cumulative trends is imagining the effects of scale. Barely 100,000 television receivers were in use in the United States in 1948. In the next year there were a million. A decade later there were 50 million. The social and psychological consequences of such phenomenal growth are hard even to contemplate, let alone predict. Indeed, in the case of television these effects are still a matter of debate, and apparently adequate research tools for measuring or evaluating them do not yet exist. Often the baseline data from which to measure changes are inadequate, and it is difficult to separate the effects of a particular technology from social or cultural trends that were present for other reasons.

Such problems aside, failure to imagine the scale of use can wholly preclude adequate perception of social and environmental consequences. The history of asbestos, for example, demonstrates the effects of scale in one of its most insidious forms (*32*). As a result of the tremendous diversity of its uses, asbestos has become practically ubiquitous. It has found its way into literally every automobile, airplane, train, factory, home, and farm across the land—and thence into the lungs of man, where, remaining as indestructible as it is in nature, it can wreak terrible havoc. So, too, with the proliferation of internal-combustion automobiles: to predict that such vehicles would chemically pollute the atmosphere more than vehicles driven by steam or electricity would have been simple; to predict that the automobile (of which there were four in the United States in 1895 and some 80 million in 1968) would become the chief source of urban air pollution would have been far more difficult.

In such cases, the exercise of trying to imagine the multiplication of a technology and its applications by several different orders of magnitude may be quite useful. Even if one cannot predict whether the correct multiplier will be 10 or 10^3 or 10^6, it will still be valuable for policy purposes, and for identifying potential hazards and suggesting research needs, to visualize the consequences of a wide range of possible alternatives rather than regularly to assume that growth will be merely linear.

A frequent and closely related problem has resulted from failure to imagine the supporting systems new technologies would demand. Witness, for example, the surface-traffic problems associated with airports, or the vast judicial backlogs resulting from the litigation of automobile-accident claims (*33*). To the extent that such conceptual failings have resulted from erroneous assumptions of scale, the multiplication exercise suggested in the latter connection might prove useful here as well.

A final difficulty, that of reliably foreseeing advances in technology itself, is perhaps less important than it might initially seem. First of all, comprehensive efforts to assess the consequences of a technology can often be effective even if they are delayed until the initial stages of research and development have been completed and the technology is at the threshold of commercial introduction. So long as one does not wait until very substantial interests have vested in a particular mode of application or use, one still has a reasonable opportunity to influence the eventual outcome by a careful examination of alternative possibilities and their implications. Indeed, even after fairly widespread distribution, the general political climate in which an innovation is introduced can have a profound effect on the thinking of the innovators themselves. Recent withdrawals of defective cars by automobile manufacturers demonstrate how public opinion and the threat of possible regulation or legal liability can modify corporate behavior far beyond the early stages of development. Second, although it is true that the options for intervention are reduced as a development moves along the spectrum from research to introduction, social intervention very close to the research end of the spectrum may foreclose unperceived future options of far greater significance and potential benefit than the harmful consequences successfully prevented. Third, whatever one's theoretical resolution of the trade-off between premature and tardy intervention, our political system simply cannot address itself intelligently and vigorously to problems that are essentially speculative and remote in time. Given a political process that responds only to relatively proximate and demonstrable difficulties, any effort to design a truly anticipatory assessment structure would almost surely fail to provide a realistic link between such a structure and the making of policy.

In general, it is easy to misconceive the role of technological forecasting as a means of controlling technological development. In the final analysis, it may be more important to foresee the full range of possibilities than to predict the most probable direction of development. The understanding of possibilities at an early stage enlarges the range of choice in the phase of innovation in which choice is still relatively easy and cheap. It also facilitates redesign of measures to evaluate effects, and thus to discern such effects before they precipitate an environmental or social crisis. If we had developed deeper understanding and better methods for monitoring DDT in the environment, for example, it seems likely that its build-up would have been anticipated earlier, its use better controlled, and alternative more selective methods of pest control more promptly encouraged—with relatively little of what can properly be called "technological forecasting."

INADEQUACIES OF FUNDAMENTAL UNDERSTANDING

One can often invent and introduce a new technology on a largely empirical basis, but a far deeper theoretical understanding of the scientific underpinnings of the technology and of its interactions with the environment is necessary if one is to make reasonably trustworthy predictions of its secondary and tertiary effects. And even if one could predict adequately without such understanding, one might not be able to demonstrate the reliability of such predictions to the satisfaction of laymen and public officials. Causal relationships will often convince when statistical correlations do not; public acceptance of warnings against smoking, for example, would almost surely have been greater if the specific causal connection between smoking and various diseases could have been established. As matters stood, elaborate and massive statistical investigations were required. For a long time it was possible to ascribe the observed correlations to factors other than smoking, especially if one were disinclined to accept the data.

But the demonstration of causes requires a great deal of basic research conducted well in advance of widespread application. Much remains to be learned about how various pollutants disperse in the environment, for example, or about how children react to various kinds of television programs. Such phenomena, whether biochemical or psychological, are often so complex that we cannot rely on empirical testing to elucidate their character. Nor can we wait to solve specific problems by research strategies designed when the problems have already become acute. We need sufficient fundamental research to guide us in the anticipation of likely problems and in the choice of the most promising remedial measures, as well as in the selection of applied research options as unanticipated difficulties materialize. Indeed the very detection of unwanted environmental effects may require sophisticated measurement techniques and theory, which can come only from fundamental theoretical understanding. Finally, in designing a research program around the introduction of a new technology, we must anticipate the worst much more often than we do now, not with the idea of slowing the development, but to ensure early detection and maximum understanding of any undesirable effects. For such understanding usually leads to the possibility of control. It is also the best form of insurance against technological surprise.

We need to know much more than we do today not only about specific technological developments and their consequences, but also about the process of technological development itself and how its direction and velocity are affected by changes in rules or incentives or by the general political and intellectual climate. How, for example, might the many parameters influencing such development be expected to reflect various changes in administrative practice or regulatory policy? A number of economists have urged that taxes be levied on auto exhaust and industrial stack emissions in order to induce behavior leading to acceptable levels of air pollution. But as recently as 1967, Ronald Ridker could state in his book, *Economic Costs of Air Pollution*, that "no one has ventured to suggest what the magnitude of such a charge should be." Such operational questions, Ridker wrote, "have not been addressed because they require empirical information far beyond our current understanding of the problem" (*34*).

Empirical information of this kind is badly needed. Research projects should be designed to ascertain the ways in which various organizations have in fact responded to different modes of regulation and to various ways of modifying incentives so that the impacts of various institutional arrangements can be better understood. Our historical experience with alternative arrangements has probably been too limited to permit confident generalizations based upon any coherent theory until we have conducted carefully controlled experiments with a number of different possibilities. Some such experiments, at least, can be performed by applying new techniques of organizational analysis in conjunction with computer simulation models. Although one must guard against putting too much faith in any model, the intelligent use of simulation methods can greatly improve upon the biased sorts of judgments that emerge from intuitive extrapolation from past experience, especially if analysis and experience can be blended in balanced judgments.

DEFICIENCIES IN THE DATA BASE

In addition to major gaps in data with respect to the actual operation of alternative modes of assessment and control, there have often been grave inadequacies in accessible information with respect to the specific consequences of particular technological developments, especially when such consequences have been diffuse and have not yet attracted widespread public interest. It seems clear that our theoretical understanding will never be so complete as to obviate the need to install and maintain comprehensive and sensitive monitoring systems, necessarily global in scope for the many technologies that generate effects over great distances, to detect low-level perturbations and thereby to make possible reliable early warnings of potentially deleterious trends, biomedical or environmental or societal, which our basic research did not enable us to anticipate.

In the absence of reliable and reproducible information for this purpose, the process of technology assessment

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becomes a matter of reconciling highly imprecise professional hunches, and the final judgment becomes highly susceptible to the influence of extraneous subjective factors. The ultimate cost is incalculable, but one can reasonably surmise that assessments made in ignorance have cheated society of many benefits that unexploited technological options had to offer, just as they have imposed on society many injuries that unwisely exploited technological options brought in their wake.

To increase the likelihood that the needed information will be systematically obtained, there must be ample feedback from assessment processes to monitoring processes. To make this possible, one must be able to identify what prior and ongoing assessments have disclosed, to locate critical gaps in available information, and to design ways to fill them. All these tasks are extremely difficult and require an ability not yet provided by current systems to marshal the available data in an orderly manner for decision-making.

Thorough understanding, built on an imaginative program of basic research and an evolving body of critical data, can only be approximated in any given case. But it is crucial that a close approximation be sought, for, in the end, good technology is ethical technology—based on a sound theoretical foundation and "dedicated to careful observation, honest reporting, and open discussion of results" (*35*).

Institutional Constraints

constraints upon the scope of individual interests

We have already seen that each of the many decision-makers whose choices collectively determine the direction of technological development typically selects from among available alternatives according to criteria that tend to underemphasize potential deleterious impacts upon large segments of the population or important sectors of the environment. The resulting divergence between the interests that the decision-maker identifies as his own or those of his clients or constituents and the larger set of concerns that he ought to take into account clearly demonstrates that existing institutional arrangements and professional attitudes leave something to be desired. Occasionally power is delegated to the wrong decision-maker—for example, to the speculative builder rather than the city planner. More often, however, the problem does not lie with the choice of decision-maker but with defects in the institutional setting within which decisions are made. Inadequacies of this sort seem to arise from several basic sources:

Market Externalities

The price system often accounts inadequately for benefits enjoyed or costs suffered by those who are not parties to a transaction. Such non-parties become particularly important for our purposes because the primary beneficiaries of technological change are seldom the same as—or at most are only a small portion of—those who suffer from its deleterious secondary consequences. Thus many of the costs and benefits of a product or process are not reflected in the economic calculations of technologists, investors, or consumers.

The concern of economists with the implications of such "externalities" for the efficient allocation of resources is comparatively recent in origin. Even the 1936 revision of Alfred Marshall's classic work on the price system discussed only those externalities that created benefits, not those that created injuries (*36*). It has been speculated that "the late recognition of the importance of external diseconomies was due as much to the association of those effects with increasing population and advancing technology—which combined to make externalities a most urgent concern of modern applied economics—as it was due to fascination with the unfettered market" (*37*).

Whatever the reason, it remained for Arthur Pigou to introduce the concept that external social costs and benefits both must be considered in any discussion of economic efficiency (*38*). And, following Pigou, economists have generally agreed that excessive resources will be invested in activities that impose costs that private producers do not have to pay, and inadequate resources in activities that confer benefits for which no payment is received, so that efficient resource allocation requires that external costs and benefits be attributed to, and brought to bear upon the price frameworks of, those firms and practices responsible for producing them.

Proposals to internalize external costs and benefits have taken several forms: tax and subsidy schemes whereby activities are charged to the extent of their uncompensated net social costs or subsidized to the extent of their unremunerated net social benefits; expansion of the size of decision-making units, so that all otherwise external costs and benefits accrue within the unit and are thus included in its profit-maximizing calculations; varying degrees and kinds of government appropriation and regulation; or various other redefinitions of legal rights. Indeed, there is a sense in which all legally established subsidies may be regarded as mechanisms for internalizing "external benefits," while all legal restraints may be viewed as mechanisms for dealing with the "external costs" that individuals may inflict upon one another. Tort liability, criminal sanctions, and contract damages—all are means by which the law forces one party to "internalize" the costs that his actions might otherwise cause another in the society to bear. But when a large number of disparate actions contribute in a cumulative and gradual way to the same costs (for example, multiple sources, over a period of years, of a severe air-pollution episode), or when certain costs are imposed thinly over a dispersed and unorganized group of people (for example, low-level disturbance of all persons in the flight path of a supersonic aircraft), the legal mechanisms now available tend to break down. Measures to improve these mechanisms in order to internalize external costs or benefits require both scientific research, to provide objective assessments of cause and reliable quantifications of damage, and political action to compel decision-makers to bear the costs they cause. Such action in turn involves an equilibration of power among competing interests that is not very closely related to optimum resource allocation.

It is not our purpose here to develop the details of the relevant economic, legal, and political theory; it is our purpose only to emphasize that such issues play an important role in the technology-assessment problem. For most of us would agree that *the objective of heightened sensitivity in technology assessment should, whenever possible, be achieved by structuring the incentives of individual decision-makers so that they are induced to alter their cost-benefit calculations to encompass wider concerns than have heretofore been given consideration.* What kinds of incentive alterations might be necessary to bring about such a result, how such alterations might be achieved, and what the administrative and other costs of such alterations might be, obviously depend strongly upon the consideration of externalities.

It cannot be assumed that a workable solution to the problem of externalities is readily available. No one has yet furnished a blueprint for a system that does not cost more than it saves, in which each individual decision-maker automatically reaps the full benefits that his decisions confer on others and pays the full costs that his decisions impose. If the problem were purely economic or legal, its solution would be difficult enough. But the problem cuts deeper. For even if we could design a legal and economic environment in which supersonic aircraft, for example, were charged the full costs that their operations would impose upon society, executives with a professional stake in the flight of an American SST, engineers with a career commitment to supersonic-transport technology, economists worried about the future balance of payments, and politicians concerned with national prestige, might well turn pre-deafened ears to the sonic boom. Such tendencies, which can be overcome, if at all, only by important changes in the values and aspirations of policy-makers and technologists, generate their own externalities, whatever the price structure and the legal setting may seem to dictate. Indeed, these considerations illustrate how deeply the decision criteria for a particular technology are embedded in the whole society and its institutions.

Competitive Pressures

In some respects the problem of externalities is aggravated by the role of competition in directing investment and innovation. Insofar as it promotes technological progress and matches the direction of such progress to the preferences expressed in the market, competition, of course, performs a valuable function. But competition rarely rewards and often penalizes behavior that is socially desirable in a larger context. Thus, for example, the chemical plant that ignores pollution will have lower costs than the plant that treats its effluents, and will thus prosper at the expense of its more responsible competitors, unless there is some sort of intervention in behalf of broader interests by a political body.

Moreover, the same phenomenon appears whenever there is competition for scarce resources, be they consumer dollars or tax dollars or political power. Thus, for example, competition is an important fact of life in the relationship of government agencies to one another. Each federal department tends to behave in a manner calculated to enhance its own relative influence and, however good its intentions, tends to overlook or at least to minimize those factors in its favorite technologies that might ultimately lead to undesirable social or environmental consequences.

This phenomenon is aggravated when particular technologies are monopolized by particular agencies. There seems ample evidence, for example, that the Federal Aviation Agency, assigned the task of promoting the SST, cannot be fully trusted to evaluate the sonic boom objectively. It is true that the Atomic Energy Commission ultimately came to recognize the dangers of fallout from atmospheric nuclear testing, but it did so only after heavy and sustained public pressure. With respect to the environmental dangers of underground nuclear explosions—including radiation leakage, seismic shock, and water contamination—the objectivity and thoroughness of the Commission's assessments have recently been brought into serious question (*39*). In a similar vein, the Bureau of Public Roads has hardly been noted for its devotion to the preservation of the natural beauty of the countryside. The Bureau of Reclamation has been reluctant to consider development of power sources alternative to building dams and hydro-electric stations. And the military services are rarely critical of major new weapons systems that promise to enhance their role in the defense posture of the nation vis-a-vis the other services, even though the net contribution to the national security may be doubtful, especially in the total context of foreign policy. It should be noted, moreover, that, by and large, each of these federal agencies is strongly supported in its views by a specialized congressional committee, which often commands the respect of the entire Congress and behind which one often finds an economic interest or professional constituency in the private sector that furnishes the committee with moral support and tangible data and arguments.

The competitive phenomenon cuts both ways, for there are vested interests not only in the continuation of some technologies but also in the suppression of others. Some regulatory agencies, for example, anxious to maintain their record of "good performance" and hence their share of power and influence, develop a dangerous bias against innovation, seldom giving adequate weight to the possible denial to society of benefits that the agencies are not chartered to foster and often giving excessive weight to the possible exposure of society to hazards that the agencies are charged to prevent. More important, such negativism tends to be supported and reinforced by private constituencies whose economic position would be threatened if their markets should be invaded by competitive technologies.

This does not mean, of course, that the reduction or elimination of competition automatically guarantees socially more responsible behavior. If the allegations of the Department of Justice are correct, for example, the introduction of anti-pollution devices by the automobile industry was delayed by an agreement not to compete in this field (*40*). In a larger sense, however, the industry was behaving competitively in its desire not to reduce its total share of the consumer's dollar by increasing the cost of automobiles by installing equipment offering little or no tangible benefit to the individual consumer.

It should be repeated that the negative effects of competitive behavior in this broad sense are not unique properties of the business-enterprise system or of profit-making organizations. Any human society in which human groupings with human aims are in competition with each other for social rewards or prestige and influence is subject to the same problem, whether one is considering profit-making enterprises, universities, federal agencies, political subdivisions, or nations. Thus, for example, if one nation is competing with another for the same market and uses a technology that is cheaper but more socially or environmentally harmful, the other nation may feel compelled to do the same. Or, at another level, a development like SST might (rightly or wrongly) be deemed critical for survival in an international contest, though dubious on a domestic basis.

The root of the matter is that no enterprise, private or public, can afford indefinitely to assume costs that its competitors will not likewise assume. The only solution lies in the direction of a mutual assumption of costs—either by contractual agreement, domestic or international, or by submission to externally imposed constraints that directly or indirectly compel all to assume costs that none could afford to assume alone.

Contraction of Goals

It has often been said that administrative bodies, surrounded by the interests they are supposed to evaluate and regulate, tend gradually to lose sight of the large purposes that attended their birth and eventually to make common cause with those interests. To the extent that this occasionally exaggerated observation reflects reality, it may be regarded as representing a special case of a general human phenomenon. Any human institution has tendencies that, unless counteracted, will over time cause it increasingly to be run for the benefit of people inside the organization and for those special outsiders with whom they have found it easiest to identify themselves. In part, such tendencies follow from rather simple failings; a lofty mandate is no guarantee against the triple danger of self-serving, habit, and subservience. In part, the tendencies in question stem from the fact that the regulated have real problems with which the regulators, with increased familiarity, become more sympathetic. And in part, they reflect the ability of regulated institutions to adduce more effective evidence and summon more articulate, coherent, and continuous arguments for their points of view than can be marshaled by the diffuse public, even in those cases in which the public is organized and motivated to speak. Finally, the appropriate ground rules and criteria may change with time as technology changes or values shift, and these changes may not be reflected either in the statutory mission of an agency or in its own perception of that mission.

Too often lacking is a set of countervailing processes to offset such tendencies. The processes required are intricate and subtle, but they can often be assisted by specific measures, such as more vigorous rotation of personnel; erection of buffers between the institution being evaluated and its closest "clientele"; effective modes of special intervention, such as the ombudsmen of the Scandinavian countries and New Zealand; and arrangements better calculated to expose for scrutiny the ground rules under which the institution is operating.

Three institutional patterns are particularly vulnerable to the dangers outlined here. The first entails the linking of evaluative and promotional responsibilities, as in the Atomic Energy Commission, the Public Health Service, or the Federal Aviation Agency. The second entails the linking of assessment authority with a regulatory mission focused exclusively on the prevention of abuses, as in the Food and Drug Administration. And the third entails the entrusting of a regulatory agency with the task of controlling an industrial activity whose mission looks very different to the regulated industry than it does to its users. Because the revenue of TV station owners or networks, for example, comes from advertisers, the mission of TV programming as perceived by the regulated "insider" is, essentially, the delivery of the largest possible number of viewers per advertising message. To the viewer—the "outsider" in the regulatory scheme—this mission is incidental at best, and, at worst, it is incompatible with good programming. Given the initial decisions (or indecisions) that led to the funding of television through advertising rather than through viewer charges or otherwise, the regulator in the Federal Communications Commission finds himself confronted with an intrinsic conflict of goals that aggravates the already strong inclination to equate the "public interest" with the interest of the regulated industry.

One might seek to counteract the unfortunate tendencies of all these patterns in a number of ways—most importantly, perhaps, by insisting upon multiple assessment and by devising effective mechanisms for assessing the assessors. But, whatever remedial measures are taken, one must not overlook the fact that the vulnerability of such institutional patterns, and of many others, may extend to all those who work with the institutions in question. The Public Health Service, for example, is responsible for much of the monitoring and evaluation of the effects of underground nuclear testing, but funds for its work come from the Atomic Energy Commission itself, creating, as one observer delicately put it, "something of a self-policing situation" (*41*). Both the Department of Agriculture with respect to pesticides and the Food and Drug Administration with respect to drugs similarly rely upon tests funded or conducted by interested parties. Indeed, even when an ostensibly neutral assessment body with no promotional or regulatory functions of its own is charged with the duty of conducting assessments at the behest of other agencies, great care must be taken concerning the authority to which the assessment body reports and the method of financing its work. For if the assessment institution (or its staff) is financed by, works closely with, or reports to an agency with a promotional or restrictive mission of its own (as is ordinarily the case, for example, with committees of the National Research Council), the assessment may be colored by the agency mission. *This circumstance suggests a clear need for a source of assessment funds independent of the institutions or agencies whose interests will be affected by the outcome of the assessment.*

Jurisdictional Limitations

When governmental entities exercise powers pertaining to the promotion and/or regulation of technological applications, the scope of their legitimate concern may be jurisdictionally confined in ways that conflict with the objective of broadening the interests that each decision-maker is encouraged to treat as his own. Territorial boundaries, both internal and international, present perhaps the most obvious example of such jurisdictional constraints. As in the case of water-borne DDT that finds its way from a farm in the United States or a field in Africa to the farthest reaches of the Antarctic, the consequences of many technological applications are no respecters of political demarcations. Yet such demarcations, not the winds and currents of the physical environment, define spheres of power and interest in the world. Thus, when we see a community discharging untreated sewage into a river without concern for its effects on cities located downstream, or when we see a nation engaging in a cloud-seeding experiment or conducting a nuclear test without concern for its consequences to neighboring countries, we are witnessing essentially the same phenomenon: any decision-making unit smaller than the area seriously affected by its decisions tends to view those effects as someone else's headache rather than its own—a kind of "political externality."

Nationally, we are beginning, though very slowly, to evolve new kinds of regional entities in response to precisely this kind of problem. For obvious reasons, progress at the international level has been more halting. The International Union of Air Pollution Prevention Associations held its first Congress in London in 1968, the United Nations has scheduled a Conference on the Human Environment for 1972, and two major international agreements with respect to nuclear weapons suggest promising possibilities for cooperation in other fields. But the fragile character of the present world order poses a formidable obstacle to the kind of international action that will become increasingly necessary as technological options with truly global consequences present themselves with ever greater frequency.

Even when political boundaries present no problem, jurisdictional limitations of other forms can still fragment technological power and responsibility—by narrowing the kinds of interests that organizations are authorized to advance. The Atomic Energy Commission, for example, recently granted a provisional construction permit for a nuclear power reactor on the Connecticut River. The states of New Hampshire, Vermont, and Massachusetts had attempted to introduce, at public hearings before an atomic safety and licensing board, evidence that operation of the contemplated facility would harm the river through injection of heated water. The board, however, ruled such evidence inadmissible as beyond the Commission's jurisdiction, and the Commission agreed. In affirming the Commission's order, the United States Court of Appeals for the First Circuit concluded from the history of the 1954 Atomic Energy Act that "Congress, in thinking of the public's health and safety, had in mind only the special hazards of radio-activity," not the additional hazards of thermal pollution. The court reached its decision "with regret that the Congress has not yet established procedures requiring timely and comprehensive consideration of nonradiological pollution effects in the planning of installations to be privately owned and operated" (*42*).

We do not intend to suggest that the Atomic Energy Commission should necessarily be given jurisdiction over all environmental effects of nuclear-reactor operations. Indeed, conferring such jurisdiction today would lead to another problem, suggested earlier, that nuclear power would then be penalized relative to fossil-fuel power not subject to similar regulation. Ideally, however, *all* power-generating technological applications would be subjected to careful assessment with respect to the full range of serious environmental effects. The present legal structure clearly fails to assure attainment of this objective.

In another recent case, a federal district court ruled that the Corps of Engineers and the Secretary of the Army had acted beyond their statutory authority when they denied the owners of dry land in Florida a permit to dredge and fill navigable waters to create an artificial island in an adjoining bay. A local health board, as well as state and federal conservation agencies, had opposed the project because it would injure fish and wildlife in the area, and the Army had accordingly denied the requested permit, following a procedure laid down in a 1967 memorandum of agreement between the Secretary of the Army and the Secretary of the Interior. But the court ordered that the permit be issued, concluding that the applicable statutes make interference with navigation—not injury to fauna or other kinds of environmental deterioration—the only lawful basis for refusing permission to dredge and fill (*43*). In this instance, as in that of the Atomic Energy Commission and many others, the legal definition of an agency's interests with respect to a technology may create artificial jurisdictional barriers to the broadening of technology-assessment criteria.

CONSTRAINTS UPON THE REPRESENTATION OF AFFECTED INTERESTS

Insofar as the course of technological development represents the sum of a number of different choices by a variety of decision-makers, our ultimate objective is not necessarily that *each* decision-maker consider every consequence of his choices, but rather that *the process as a whole* somehow take every consequence into account. If every potentially affected group accurately perceived its interests and were appropriately represented at a suitable point in the process, constraints upon the individual interests of each decision-maker—because of market externalities or basic attitudes or other considerations—would present no serious problem.

Such constraints are troublesome only when the process as a whole fails to assure adequate representation. But this will unfortunately be the case whenever the process in question remains wholly private. For if a technology is supported entirely by private investment, with no governmental involvement whatever (promotional or regulatory or otherwise) in its development or use, then some affected groups will inevitably have had no opportunity to bargain with, or otherwise to influence, the decision-makers responsible for the lines along which the technology has evolved.

The government is always involved, of course, in some indirect way—even if only by providing the rules and facilities for bringing suits for damages, the threat of which forces individuals to consider at least some of the potential effects of their activities upon others. Moreover, whenever a governmental body expressly chooses to take—or to avoid—an even more active role with respect to a given technology, it creates a decision-point at which the whole range of affected interests might, at least theoretically, have an opportunity to be heard. The action or inaction at each such point will affect a broad variety of individuals and groups in the future, not simply those with currently recognized stakes in the technology. Perhaps an idealized system of technology assessment would provide effective representation for every potentially affected interest at every such point. In practice, however, this is impossible. Whatever effort is made to alert them, many individuals and groups will remain unaware of developing technologies or of their potential effects upon them. Others may be misinformed or may react emotionally or irresponsibly. Often the people affected may belong to future generations, or may be among those who, like ghetto residents until recently, are not politically articulate. The adjustment of conflicting interests and values is time-consuming and costly, and may be so to a degree not justified by the gains, particularly in light of benefits foregone as a result of the discouragement of innovators or as a result of delays in the progress of technology. Far from being the inevitable and autonomous process often pictured, technological innovation often depends on a delicate balance of influences that are not always on the side of beneficial change.

Both to avoid cumbersome delays and to assure the representation of inarticulate interests or diffuse public concerns such as the preservation of future options, it may be necessary to create surrogate representatives—public intervenors—to speak on behalf of such interests and values. Having such representatives closely involved in the decision process may forestall mobilized political opposition to a development at a later date simply by anticipating the sorts of objections that might be raised and redirecting the development so as to meet them. The earlier the stage at which remote interests are injected into decisions with respect to the development or application of technology, the less likely it is that more costly changes in plans will be required later. Highway planning furnishes a good example of the application of this principle. At present such planning reflects largely engineering and economic considerations, with only minor attention to social and environmental concerns. Increasingly, plans are being disrupted or abandoned at late stages as a result of political agitation by suddenly alerted groups. Thus, what should have been an integral part of the planning process itself becomes the subject of political in-fighting, with all the distortions and misperceptions that such conflicts usually involve.

These considerations imply that broad public participation in the assessment process ought to be encouraged, and public apathy overcome, in the early stages of major technological developments, at least in those instances in which such stages can be identified in advance. Accordingly, although the panel does not believe it either practical or desirable to open the whole process of technological assessment and decision-making to public view, we do believe it important to assure that the evidence and arguments on which major decisions are based will be open to public scrutiny and will be subject to timely review in appropriate public hearings.

CONSTRAINTS UPON THE COORDINATION AND FOCUSING OF RELEVANT EFFORTS

Despite the many institutional deficiencies thus far identified, the present system might still be improved significantly with respect to the broad objectives outlined in Chapter III but for serious limitations upon the

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system's capacity to direct its diverse energies in any coherent way toward the achievement of such objectives.

An instructive contemporary example is furnished by a 1968 legislative proposal (S. 2658) to increase the size and weight limits for motor truck carriers and thus to permit the expansion of an existing technology (*44*). The Senate Committee on Public Works, supported by the analyses of the Bureau of the Budget and the Department of Transportation, recommended the proposed increase in a report that considered only the physical capacity of the interstate highway network to accommodate the larger trucks and the possible contribution of such trucks to traffic accidents. Just as the President's Advisory Committee on a National Highway Program and the relevant congressional committees had given no consideration whatever, in recommending the original Federal Highway Act of 1956, to the kinds of environmental deterioration that might result from the proliferation of highways and the growth of automotive traffic, so too the relevant agencies and committees ignored environmental concerns in assessing the 1968 legislation.

The President's Advisory Committee in its 1955 study had attempted to justify its failure to consider alternative modes of transportation by noting that "other Government agencies and special committees" were concerned with other transportation media (*45*), and the entities responsible for evaluating the 1968 proposal could likewise claim that an imposing array of organizations had examined and were still exploring such problems as air pollution from automotive exhaust fumes and aesthetic debasement from ever larger trucks on ever wider and more extensive highways. In light of all other pertinent assessments, who was right: those who defended the narrow scope of the Senate's 1968 assessment or those who insisted that a broader range of impacts should have been evaluated and, in effect, a wider circle of constituencies alterted and consulted?

The fact is that one cannot really decide, on the basis of the information available, precisely what questions the Senate Committee should have asked when S. 2658 came before it. For there existed then and there exists today no reliable source to which the Congress—or anyone else—can turn for a "snapshot" of the assessment situation even with respect to so uncomplicated a technological proposal as that embodied in S. 2658. One simply cannot obtain a clear picture of what prior and contemporaneous evaluations have been or are being made, what their frames of reference and findings were or are, and what issues remain inadequately explored. Without such a picture, one is tempted either to pass the buck—to assume that somebody, someplace, has asked or will ask the right questions—or to dissipate one's efforts in as "comprehensive" an evaluation as one can imagine, while paying the inevitable price of duplicated effort and, worse still, superficial analysis. The natural tendency is to err on the side of buck-passing, and the inevitable result is that incremental decisions, such as periodic increases in truck size and weight, may accumulate so much momentum and consolidate so many interests that continuing technological development may pass beyond any effective control even by those who appropriate the funds that fuel its progress.

Because such evolutionary processes are the rule rather than the exception—recall the ubiquitous "tyranny of small decisions" (*46*)—and because incremental choices can result in cumulative adverse impacts and opportunity costs as serious as those caused by "one-shot" decisions made on the basis of inadequate assessments, the panel believes that a critical obstacle to improved assessment and response is the lack of any mechanism to monitor and coordinate the many assessment and decisional systems—fragmented in location, in responsibility, and over time—that together comprise the technology-assessment apparatus of our society. Without such an integrative mechanism for comprehensive information management, the basic flaws in existing systems—such as narrowness and inconsistency of criteria; lack of detachment, professionalism, and continuity; inadequate representation of diffuse or subtly affected interests—are virtually certain to persist.

Nor will it suffice to bring the myriad activities of fragmented assessment systems into intellectual and informational focus. It must be recalled that our difficulties with respect to the management of technological change derive less from inadequate perception than from defective response. In the long run, a broadening of factors and a readjustment of priorities are needed within the innumerable cost-benefit analyses that are continually being made wherever technological change is engineered—throughout the private sector and the executive branch. Such a broadening and readjustment can ultimately be effected only by those at the front line of decision-making, working at industrial drawing-boards and on executive balance sheets. But individuals and organizations disposed toward such a realignment will be unable to achieve it unless the present play of forces within government and industry is significantly altered. If such an alteration is ever to be accomplished, it will require incentives and pressures originating in public concern and flowing into the political process, where they can be shaped and directed toward key points of decision in executive agencies and departments and in the private sector.

It is primarily through the legislative and judicial branches that such incentives and pressures can receive the necessary direction and impetus, for it is Congress and the courts that can most readily become forums for the dissident and the disadvantaged in our society, and it is in the legislative chamber, acting as a committee of oversight, and in the courtroom, acting as an instrument of accountability, that the concerns for human values and a healthy environment can most vigorously be pressed upon a system otherwise notoriously loathe to move. The difficulty is that at this level, too, there exists no mechanism to integrate and focus the many disparate strands of concern and sources of pressure—to mold them into a powerful constituency for more responsible and responsive technology assessment. We have merely a spate of proposals in Congress, an occasional note of alarm from the Executive, and a few sporadic lawsuits brought by aroused citizens. Only when the energies represented by these diverse sources are orchestrated creatively and channeled continuously toward the tasks at hand will there be real hope of eventual progress.

CHAPTER V. APPROACHES AND RECOMMENDATIONS

General Principles

Thus far, we have described our conclusions about how decisions influencing technological change should ideally be made. We have urged that such decisions ought to reflect a wider circle of concerns than they have in the past; that they should attribute greater importance to the preservation of future options; that they should be preceded and accompanied by more comprehensive efforts to reduce uncertainties through basic understanding; that they should build on a broader base of public participation; that they should be brought into greater harmony with one another through more sophisticated efforts to achieve consistency of criteria. And we have attempted to trace the myriad constraints, both conceptual and institutional, upon society's capacity to achieve these objectives. We turn now to perhaps the most difficult phase of our task—the prescription of an agenda for change.

We preface our discussion of more operational matters with a number of observations about the spirit in which we believe a program of change ought to be formulated. Many of the goals expressed in this report are, at bottom, the goals of better government and, indeed, of a better world. To approach such goals with rigid formulae, or even to proceed in the belief that goals of this kind can be fully achieved rather than only approximated, would blunt the effort in advance. The only strategy with which confident steps can be taken eventually to move the system we have described in the broad directions suggested here is an evolutionary one.

The pervasiveness and complexity of the problems we have addressed, the scale and variety of the private and public interests affected, the nation's inexperience and the inadequacies of our knowledge, all call for a modest beginning, not a wholesale attack. Our search, therefore, must be for a manageable, and yet significant, point of departure. As we said at the outset of this report, the question before the panel is how we in the United States can best *begin* the awesomely difficult task of altering present evaluative and decision-making processes, and how we can best do so without sacrificing the benefits that those processes, in the service of continuing technological progress, have to offer.

Clearly, the processes we seek to change are too bound up with the very fabric of our society to admit of sudden and sweeping alteration. But some of those processes at least are more amenable than others to purposeful change. At several points in this report we have noted the growing significance of federal programs and policies in the evolution of technology. We have observed that technological development in the private as well as the public sector has become increasingly dependent upon actions taken by Congress and the President, upon federal appropriations and legislation, upon the missions and practices of a wide variety of executive agencies and administrative bodies. Frequently, in describing what have seemed to us to be important deficiencies in present processes of technology assessment and choice, we have taken our cues from the experience of the federal government itself.

If we seek a place to begin, then, what more appropriate starting point could there be than the federal government's present involvement in the support and regulation of technology? It is at the federal level that the greatest pressure for action is now felt, and surely the case for action by the federal government is stongest in those areas in which federal policy already plays a major role in technological development. There is much to be said for the view that the federal government ought to put its own house in order before it seeks to impose new requirements for state or local action or new standards for the private sector. If a pilot program initiated within the federal government and limited to technological developments and applications significantly molded by federal policies could be carried out imaginatively and energetically, it could eventually serve both as a stimulus and as a demonstration, leading to comparable activities in state and local governments and in the private sector, or perhaps to gradual extensions of the federal program itself. If the federal government can point the way to more responsible management of technological change, it will have accomplished no mean task; if it cannot, little more can be expected of other institutions in our society.

We have already described a variety of federal activities that might fall within the purview of the sort of pilot program we contemplate. Any such program would invariably become involved, for example, with federal support for highway and airport construction; federal participation in water-resource development and weather-modification research; federal sponsorship of supersonic transport and of nuclear-power generation; foreign aid for the support of agricultural technology in developing nations; federal promulgation and enforcement of safety standards and regulations in the drug, automotive, and other industries. *The analysis of this report does not call for the alteration of any of these activities* (though alterations might ultimately be deemed wise) *or even the assumption of their technology-assessment responsibilities by a new organization* (though reassignments of responsibility might eventually be deemed desirable) *but simply the creation of a supplementary set of mechanisms designed to inject into the activities falling within its purview a new and broadened set of perspectives.*

The members of the panel are persuaded, for the reasons developed in this report, that the creation of such additional mechanisms in the federal government is a matter of urgency. Before attempting to describe how the mechanisms we envision might function and how they might be organized, we think it useful to articulate here the broad principles that our analysis suggests should guide the design of *any* improved assessment system within the federal government, however narrow or expansive the range of its substantive technological concerns might be.

PLURALISM

As one panel member recently testified, "the most important determinant of our future ability to use technology effectively and wisely to accomplish human ends will not be the existence or absence of formal mechanisms, governmental or private. Even the most centralized modern technological society—and ours is one of the least centralized—is highly pluralistic. No one does, or can 'mastermind' it—not even the whole Establishment, if there is such a thing. Decisions that do, or should, employ modern technology; decisions that have effects which science and technology can anticipate: such decisions are made by millions of people at millions of moments" (*47*). It follows that intelligence about technology can be effective only if it is widely distributed. It cannot be buried in a Department of Technology Assessment or a Council of Technological Advisers, however useful such organizations might be for some purposes. *What is needed, clearly, is a wide diffusion of deeper* *understanding about technology and deeper concern about its implications.*

In part, the panel's demand for such diffusion is a corollary of its belief that decisions affecting the course of technology and hence the course of history require the broadest possible public participation and should not, even if they could, be delegated to narrow elites, whether scientific or political. But even apart from this value judgment, grave deficiencies would inhere in any self-contained and centralized assessment operation, however well-intentioned and dedicated.

First, it is clear that no assessment mechanism broad enough to achieve the objectives this report envisions—even if limited to the sphere of federally supported or controlled technology—could possibly command the range of expertise needed to make competent assessments of all the problems with which it might be confronted. Hence any mechanism we recommend must be empowered to commission external research, partly by contracting out defined assessment tasks to private agencies or groups, and partly by extending grants to finance unsolicited proposals for assessment studies by independent scholars in universities or other institutions. Only with such a capacity could a new mechanism marshal the necessary expertise without invariably relying upon studies funded or staffed by interested parties. Given this capacity, both the reality and the appearance of objectivity would be enhanced, as would the ability of the new mechanism gradually to instill new ways of thinking and new emphases throughout the professional and academic communities, and thus to contribute to the improvement of technology assessment generally.

Second, even if it could be entirely self-reliant, no assessment mechanism in government could be trusted to retain its detachment and open-mindedness unless it were continually subjected to independent external criticism. One of the defects of existing systems is their excessive reliance upon unitary mechanisms to make particular assessments, with the result that distorted or partial perspectives too often become dominant. *Any change we recommend should therefore seek to induce as many different elements of society as possible to involve themselves in broadened assessment efforts.*

Indeed, our panel envisions not a single assessment mechanism but a network of such mechanisms extending throughout government and the private sector. The components of such a network already exist, but they have not developed a consistent framework of criteria with sufficiently wide perspective. They tend to confuse the technology-promotion, technology-regulation, and technology-evaluation aspects of their tasks. There is relatively little communication between those with technology-assessment and evaluation responsibilities in different parts of government and industry. Their tasks are perceived in overly specialized terms, and much of the technology assessment that goes on in programming and planning offices is not recognized as such. *The objective of any proposal we make—whether or not limited to federally influenced technology—should not be to transfer these assessment responsibilities to a new organization or to duplicate existing assessment activities in a new setting, but to subject such responsibilities and activities to critical review and constructive guidance in the hope of developing consistent principles and higher standards within a pluralistic frame. Any new assessment structure in the government should therefore supplement and coordinate existing mechanisms rather than supersede them. It should perform the function of examining and influencing the ground rules and criteria of evaluations that are conducted within the agencies themselves.*

Scientists and engineers today manifest a growing tendency to view their professions and their responsibilities to society in a far broader context than ever before. This is especially true within the universities, partly stimulated by the interest of the newer generation of students, and partly reflected by the emergence of new courses focusing on the social and environmental impact of engineering choices and technical decisions. In the business community as well, we have noted the emergence of social conscience with little parallel in our historical experience. But there is as yet no real focus for these new attitudes and activities. The creation of a new identity for technology assessment within the government, even if little or no change were made in the formal responsibilities of existing organizations, could have a galvanizing effect in stimulating interest in the subject, providing an outlet for this interest within the professions, and channeling it in constructive directions. There might develop, as a byproduct, an improved professional literature of assessment, with the kinds of refereeing, citations, and standards characteristic of other types of scientific writing. But whether technology assessment itself will become an independent profession, or whether it will be characterized more by a new set of attitudes on the part of working scientists and technologists inside government and industry, is not clear. Probably it will be—and should be—a mixture of both.

Unless the broadened criteria and perspectives developed by a new assessment entity find a place not only in the thinking of scientists and engineers but also in the planning of entrepreneurs and executives, the impact of any such entity will be superficial. For even if the entity is confined to areas of technology strongly influenced by federal action, it will need to draw on the resources of the corporate community if it is to perform capably, and it will ultimately have to influence the decision-making processes of that community if it is to prove truly effective. It is therefore crucial that any new mechanism we propose foster a climate that elicits the cooperation of business with its activities. Such a climate cannot be maintained if the relationship of the assessment entity to the business firm is that of policeman to suspect. The needed climate requires that private industry be encouraged to find its own technical solutions—not compelled to follow solutions formulated from above.

Most businessmen will accept rather broad social goals so long as they can identify themselves with the effort and can do so without being placed at too great a competitive disadvantage. It seems clear, for example, that government sponsorship and leadership could induce the private development of far "cleaner" means of automotive propulsion—despite the fact that each individual company, without such leadership, might feel unjustified in undertaking the costs involved in the necessary changes. To that end, the government might well establish standards calculated to achieve specific environmental objectives. But for government to do more than that—for it to lay down detailed design specifications—would alienate the very community to which the government must ultimately turn for competent technical work.

Given the richness of contemporary technology, it may be expected that a number of alternative technical possibilities will emerge in response to each problem—that there may, for example, be several efficient solutions to the problem of automotive air pollution short of scrapping internal combustion entirely and substituting steam or electricity. The optimal course is likely to result from an engineering balance of costs and benefits rather than from immutable first principles. Any new assessment mechanism that respects the importance of a pluralistic approach, and hence wishes to enlist the competence of industry, must be ready for such situations and must be prepared to follow the engineering analysis to the necessary depth rather than adhering inflexibly to a preconceived set of answers. Business will understand this sort of approach if it is followed consistently; no other approach is likely to enlist the assistance of this vital resource.

NEUTRALITY

Any new technology-assessment mechanism must maintain as detached and neutral a stance as possible toward each issue that comes before it. We have already seen that a central deficiency of existing mechanisms for assessment is that they fail to separate promotion or protection from evaluation, and thereby compromise both their integrity and their credibility. To overcome that deficiency, *any new mechanism we propose must be carefully insulated from direct policy-making powers and responsibilities.*

Thus the mechanism must not be charged with responsibility for the accomplishment of any technological mission. Unlike the Federal Aviation Agency, for example, it must not be entrusted with the realization of a supersonic transport. Unlike the Public Health Service, it must not be held accountable for the promotion of water fluoridation. Unlike the Department of Transportation, it must not be held responsible for the promotion of new or more effective means of transportation. Unlike the Department of Interior, the Department of Agriculture, the National Science Foundation, and the National Aeronautics and Space Administration, it must not be empowered to promote or finance weather-modification efforts.

Conversely, any new entity we recommend must not be charged with responsibility for the reduction or control of any technological problem. Unlike the Food and Drug Administration, it must not be held responsible for the protection of the public from hazardous drugs. Unlike the Atomic Energy Commission, it must not be held accountable for the avoidance of excessive radiation. Unlike the Federal Water Pollution Control Administration or the National Air Pollution Control Administration, it must not be charged with preserving the quality of environmental resources against technological incursions. *Above all, it must be given no authority to screen or "clear" new technological undertakings.* To make its approval a prerequisite to action by any other agency or organization would immediately deprive it of its unique perspective as an entity with no ax to grind.

Given the current popularity of proposals to entrust some environmental agency with the power to censor all technological developments and to forbid the introduction of those deemed excessively injurious, a further word on this subject seems in order. The panel strongly doubts that such vast authority could be lodged in any agency without subjecting it to external political pressures that it could not resist and thence leading it to prompt corruption and ultimate collapse. At a minimum, the panel is certain that entrusting such sweeping powers to a new assessment entity would rob it of any special claim to objectivity and would render its judgments at least as suspect as those of any other regulatory body. But even if these consequences could somehow be avoided, the panel would emphatically oppose any scheme that would empower an agency to decide, on behalf of something called "society" or "the environment," which technological developments will be permitted and which prohibited. Selections among alternative technologies require that choices be made among competing and conflicting interests and values. To the extent that those choices are made and enforced collectively rather than individually, they are essentially political in character and must therefore be the responsibility of the politically responsive branches of government and of those publicly accountable bodies that are specifically entrusted with regulatory responsibilities in narrowly circumscribed areas. The making of such choices is, in principle, indistinguishable from the resolution of the many other conflicts that beset society. To entrust the resolution of all those conflicts to a single, all-encompassing authority would be incompatible with representative government.

Any new assessment entity we propose, therefore, should be empowered to study and to recommend but not to act. It must be able to evaluate but neither to sponsor nor to prevent. We confront, however, something of a paradox, for though we wish to assure the neutrality of the new mechanism, we wish also to assure that it be influential. The panel has no thought of urging the creation of another organization simply to add one more voice to the many that already cry out for change. *Thus, while it must itself seek to be apolitical, any new assessment mechanism must be located close to the centers of power in the political process; given the vast powers of the contending interests that will surround it, any organization less centrally situated would have no realistic hope of materially influencing public policy.*

There must therefore be a close relationship between some component of the new mechanism and the President in his political capacity; and some component of the mechanism must be linked closely to Congress, either to that body as a whole or to one or more congressional committees, whether joint or parallel. Any such congressional component—whether an instrument of Congress as a whole or of one or more committees or both—must be empowered at the very least to review the work of the executive component and also to undertake studies on its own initiative.

Without connections of this kind, any new mechanism would invariably lack force vis-a-vis the executive bureaucracy and the government-industrial establishments, both within the executive branch and in congressional processes, whether related to substantive legislation or to appropriations. With such connections, however, the prospects for an effective system would be more favorable, particularly since it would then be feasible to lodge, within the component linked to Congress, the power to obtain all pertinent information, by subpoena if necessary, from any government agency. Such connections could also facilitate communications between the executive component, the congressional component, and the general public, without the usual process of clearance through the Bureau of the Budget for conformity to "the administration's program."

Some might wish that the priorities assigned to technological effort and research could show the way for the political and social priorities of the future. This would in the extreme case amount to technocracy, with "expert" judgment replacing political discourse as the mode by which society determines its goals and directions. But in the real world it is more likely that scientific and scholarly priorities will be determined by social and political priorities than *vice versa*, at least when it comes to the applied science, technology, and policy-oriented scholarship with which we are concerned in this report. *The most we can hope for in creating a new mechanism for technology assessment is to introduce a greater degree of objectivity into the process and to inject a body of criteria and assumptions that reflect a wider set of interests and values than do the specialized organizations currently engaged in fragmented assessment activities. We can hope to raise the level of political discourse; we must not seek to eliminate it.*

Indeed, the best guarantee of objectivity might well be to open the new mechanism to as wide as possible a range of countervailing influences rather than to attempt to shut out such influences altogether. We have already noted the need to accompany any new assessment mechanism with

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surrogate representatives or ombudsmen to speak on behalf of interests too weak or diffuse to generate effective spokesmen of their own. Citizens' committees or advisory panels of affected laymen might prove helpful but obviously will not suffice. Means must also be devised for alerting suitable representatives of interested groups to the fact that a decision potentially affecting them is about to be made, and for informing such representatives of the issues presented by that decision. *Whatever structure is chosen, it should provide well-defined channels through which citizens' groups, private associations, or surrogate representatives can make their views known and, if insistent, be granted a hearing*, though mechanisms should also be provided to filter out for summary treatment truly frivolous or irresponsible claims.

Opportunities to intervene should come early in the decision-making process so that needless controversy is avoided later and so that participants can effectively influence the outcome. To increase the likelihood that the views expressed will receive adequate weight in the final assessments and decisions, care must be taken to secure a wide diversity of lay and professional personnel in the assessment entity itself and to guarantee thorough public review, though measures must also be devised to assure that at least the early stages of the assessment process, when experts should be encouraged to speculate candidly, will not later be exposed to embarassing public scrutiny.

Thus it is through procedural arrangements calculated to elicit the broadest possible participation in its work, rather than through devices designed to separate it from the world of power, that a new assessment entity can best be protected from forces that would threaten to narrow its perspectives and thereby subvert its neutrality and integrity.

CAUTION

It may seem superfluous to do so, but the panel wishes to stress the need for a cautious approach to the development of new assessment institutions—an approach that does not confuse the urgent need for action with a mandate to ignore the risks that such action might entail.

One such risk flows from the problem of information overload and the limited attention span of the political process. Thus, the very fact that one must necessarily place some issues much higher than others on the technology-assessment agenda means that certain activities will be assessed more deeply than others and may thus be burdened with a larger share of the environmental and social costs that they generate. We have already noted that this sort of imbalance can create a serious misallocation of economic resources, and *we emphasize the problem here in order to highlight the importance of assuring that priorities in the assessment process be set along reasonably objective lines and that assessment criteria be developed and enforced in reasonably consistent ways.*

Another kind of difficulty results from the mixed values of technological consequences. Almost always, as we have noted, they will be perceived as beneficial by some and detrimental by others. The options made available by a given technology or by a particular way of introducing it encourage a reordering of social structures toward an equilibrium consistent with the newly relaxed constraints. Even when the ensuing configuration is plainly beneficial from some appropriately "public" perspective, various groups and institutions might well be worse off, either briefly or for long periods, as a result of the change. The entirely natural opposition of such groups to the technological development in question, already a barrier to many forms of innovation, might simply be accentuated by improved technology assessment. For such assessment, in identifying and publicizing the adverse side-effects of technological change to various sectors of society and of the environment, might arouse the opposition of powerful interest groups at times and in directions quite at odds with the "general welfare," however defined. Experience with the misuse of danger-identifying assessments as weapons to suppress competing technologies in the construction and transportation industries, to name two examples, at least counsels caution.

Indeed, even an assessment process designed to stress the potential *benefits* of technology by identifying its optimum uses might result in stifling desirable changes. In discussions of the future of audio-visual education, for example, the contrasting implications of two different technological choices have been noted: first, instructional TV programs broadcast from a central source to all schools in a given city; second, film or videotape cartridges located in school libraries for use at the teacher's initiative. Choosing the first alternative would obviously diminish the flexibility of teaching schedules and restrict the play of individual teacher preferences and styles, though it might prove more efficient in an economic and organizational sense and might permit wider dissemination of the "best" materials; choosing the second alternative would permit teachers to adapt television materials to their own educational approaches and tastes—in timing and in content.

A desire to keep the individual teacher in the center of the picture might lead one to prefer the second alternative. But the educational philosophy of the established bureaucracy might be rather different. Perceiving greater freedom for individual teachers as a threat to centralized control, and basically distrusting the judgment and competence of individual teachers in comparison with those of their own more expert consultants, members of the educational establishment might well be alerted to oppose the decentralizing alternative. Unless those who stand to gain from a technological option that disrupts the system are as well organized and influential as those with a stake in seeing the system remain unchanged, the early and persuasive identification of which technological choices would produce which benefits could prove sadly self-defeating. *For this reason it is particularly important to couple improved assessment with improved methods of representing weak and poorly organized interest groups.*

A third danger follows from the fact that it is ordinarily simpler to foresee difficulties than it is to foresee the technical or social inventions that can overcome them. Innovation, whether technological or social, requires a certain measure of faith and missionary zeal, a willingness to proceed despite apparent problems whose solutions are not yet foreseen (*48*). There is a delicate balance between such faith, on the one hand, and rational analysis, on the other—a balance which must not be tipped too far either way. *At the very least, new assessment institutions should be cautioned against the tendency to stultify progress by magnifying risks or difficulties and ignoring the possibility of finding solutions as problems arise.*

A fourth danger is one that inheres in every exercise in seeming rationality in politically charged areas of discourse. Just as systems analysis has on occasion been used to provide a misleading mantle of objectivity for essentially predetermined value preferences (*49*), *so too there is a risk that technology assessment, unless continually subjected to independent criticism and countervailing pressures, may become a weapon for individuals and groups in defense of their own narrow interests.*

A final hazard is that the superposition of new review and assessment mechanisms upon those already existing in the federal government and elsewhere may exert an excessively inhibitory effect upon innovative activity generally. Although we have recommended that new assessment institutions be given no formal clearance authority, we recognize that they will, if properly designed, prove highly influential. Their very existence could create large new worries for the innovator; how a proposed technological change would be viewed in the eyes of the new assessors could pose a perplexing question for business.

The force of this consideration is obviously weakened to the extent that new assessment mechanisms are restricted to areas where federal decisions already play a crucial role, but even mechanisms thus confined will undoubtedly impose *some* higher costs. It should be noted, however, that such added costs can ordinarily be recovered in the eventual return on the investment, through higher prices. If it is feared that permitting the price system to reflect such costs would move vital products or services beyond the reach of certain segments of the population, then that problem can be addressed separately as an issue for income and welfare policy. When, for political or other reasons, investors consider reliance on future use of the price mechanism unwise, the government might assume enough of the initial risk (as it has with respect to atomic-energy development) to overcome the potentially retarding effect of assessment, eventually recovering the expense by a tax on the resulting private industry, by a direct rebating scheme, or, in the case of a technology remaining in the public sector, by a governmental charge to users.

However the costs imposed by better assessment are borne, it is important to remember that the whole point of such assessment is to save society in the long run even *higher* costs that less disciplined technological development would be likely to inflict. The panel very much doubts that altering the cost-benefit calculations made by those who guide the course of technological innovation and diffusion will retard the total *quantity* of innovative activity; it seems far more likely there will simply be a change in the *quality* of innovation—a change that will quite properly reflect the broader concerns that have heretofore been given too little weight.*

Institutional Guidelines

To summarize, the analysis thus far developed argues for the creation of new institutions for technology assessment in the federal government. Whatever their precise structure, such institutions:

1. Should be developed with a cautious regard for the potential hazards latent in their operation.
2. Should provide a continuing and critical evaluation of assessment and decision-making processes in those areas of technological development in which federal programs or policies play a significant and direct role.
3. Should serve not to supersede existing mechanisms for technology assessment but rather to enhance the consistency, breadth, and objectivity of their criteria for decision, the comprehensiveness and accuracy of their analyses, and the openness of their processes to wide participation by all potentially affected interests.
4. Should possess an effective capacity to stimulate in both private and public sectors an increased awareness of, and competence in, the requirements of improved technology assessment.
5. Should foster a climate that elicits the cooperation of the professional and corporate communities with the new assessment activities while encouraging self-directed initiatives within those communities toward more sensitive and comprehensive assessment standards.

*One member of the panel, Morris Tanenbaum, does not fully agree with the other members on this issue. His separate views are set forth in Appendix B, pgs. 148-150.

6. Should be charged with neither promotion nor regulation of technology but should be held accountable for maintaining, in the policy alternative and recommendations derived from their research, as neutral and detached a stance as possible.

7. Should operate at a strategic level in the political process, close to both the legislative and executive branches, in order to attract the most competent and imaginative personnel available and to enhance the quality of governmental response to the problems and opportunities of technological development.

8. Should remain open to the widest possible range of responsible influence by all potentially interested groups and by surrogate representatives of interests too diffuse or too weak to generate effective spokesmen of their own.

9. Should possess the ability to establish for themselves, and to suggest for others, a system of priorities among the multitude of possible assessment issues and activities in a manner calculated to promote rational and timely public identification of salient problems, opportunities, and points of decision.

Specific Functions

Keeping in mind the broad guidelines set forth above, guidelines that should be considered in the design of any new technology-assessment mechanism or set of mechanisms in the government, we turn now to an enumeration of the kinds of functions that we would expect a new mechanism to perform:

1. Examine particular areas of technology by contracting with outside organizations to undertake studies of specific problems defined and selected by it. Such examination would be confined, at least at the outset, to technological developments or applications that are

sponsored by the federal government or are otherwise affected in a major and direct way by federal activity. The primary effort would be to project social and environmental effects in the most comprehensive terms possible, with particular attention to dimensions of impact and options for policy that other assessments of the same area have failed to explore fully. From time to time, it might also be possible to experiment with assessments centered not on particular areas of technology but on areas defined in terms of the environment, the society, or the individual, in order to investigate the cumulative impact upon these elements of all technologies with which the federal government is strongly involved (*50*).

2. Sponsor basic research on theoretical problems and issues related to technology assessment by extending grants to support independent studies proposed by other governmental agencies, universities, or non-profit organizations. Unlike the contract program, the grant program need not be restricted, even at the outset, to government-sponsored or government-affected technology but might properly range over the entire set of concerns pertinent to the intellectual underpinnings of technology assessment and decision-making.

3. Review specific assessments performed by other government agencies or departments, either on its own initiative or by request from other agencies, from selected persons elsewhere in government, or from responsible spokesmen of various private interests. Such review would be confined to an evaluation of (a) the criteria and procedures employed in the assessment process, (b) the nature and technical adequacy of the evidence relied upon, and (c) the representation of potentially affected interests.

4. Conduct studies of continuing assessment systems in various parts of the government, such as the Food and Drug Administration, the Federal Trade Commission, or

the Federal Communications Commission, again evaluating the adequacy and comprehensiveness of (a) the criteria used, (b) the evidence employed, and (c) the interests represented.

5. Maintain an information center on technology assessment, which would in time become a primary source of critical data with respect to pertinent activities carried on in government, in the universities, and in other organizations. As a comprehensive information-management system, the center should be designed to support systematic inquiry into past and present assessment activities and findings, with emphasis upon identifying gaps in the resulting body of data and evaluation. The center would issue bibliographies, abstracts, project lists, and state-of-the-art summaries on its own initiative. It would also operate an inquiry service to answer appropriate questions directed to it by any government official or private individual or group.

6. Issue an annual report on technology assessment (a) summarizing its own activities, (b) reviewing the work of technology-assessment mechanisms throughout the government, and (c) describing new methods that had been developed, new problems that had been encountered, and general issues that had emerged from an across-the-board examination. Largely educational in purpose, the report would seek to develop a framework for public discussion of such issues and would seek to publicize matters relevant to technology assessment that seem unlikely to receive adequate public attention through other channels.

Most importantly, the annual report would suggest priorities as to the most pressing problems and the most promising opportunities in technology assessment. The system of priorities thus formulated would guide the work of the new mechanism through the subsequent year, enabling it to control its own agenda and to accept or reject proposed projects according to an explicit system of problem selection—a capacity that could prove invaluable in politically volatile situations.

The priorities proposed in the annual report would reflect such considerations as (a) the urgency of an issue, in terms of the degree to which irreversible consequences might be expected to flow from postponement of assessment or action, or in terms of the imminence of a large commitment of resources; (b) the lack of adequate effort devoted elsewhere to the issue; and (c) the contribution that an attempt to deal with the issue might be expected to make to the improvement of technology-assessment methodology and the development of consistent technology-assessment principles.

For such a priority-setting system to function well, it must be supported by ways of making effective quantifiable guesses about technological trends and consequences; of reviewing the objectivity, thoroughness, and accuracy of prevailing estimates, claims, and warnings; of positing optimal sets of questions for interim assessments in light of other, related efforts; of conceiving the possible contents of still-unformed assessment doctrines; and of learning quickly who is looking at what problems and how adequately. Both the grant program and the information center will obviously prove critical to the development of the tools and the data necessary to the effective setting of priorities in terms of future need rather than past habit and present power.

7. Sponsor conferences and symposia on specific areas of concern bearing on federally supported or regulated technology and publish the proceedings thereof. Emphasis might be placed on international participation and on stimulation of cooperative studies between countries with technology-assessment problems crossing international boundaries.

8. Prepare in-house policy papers recommending specific actions to Congress, the President, executive

agencies, or administrative bodies. Such papers might recommend (a) new programs of research and development; (b) changes in policy with respect to the stimulation or regulation of a technology with which the federal government is already involved; (c) improvements in the continuing procedures followed by assessment mechanisms in various parts of government; (d) readjustments of the criteria, ground rules, or breadth of representation in a pending assessment within the government; (e) reassignments of responsibility among government assessment mechanisms; or (f) the creation of entirely new evaluative or regulatory entities.

Before such policy papers are prepared, and perhaps also before commissioned reports are approved for publication, public hearings should be held if requested by or on behalf of any potentially affected group. Any final report should then include a summary of the hearing and a statement of the data and arguments upon which the report's conclusions are based.

Organizational Arrangements

The panel has devoted a significant part of its attention to consideration of specific institutional structures that could perform the functions enumerated above in conformity with the general principles and guidelines set forth in the opening sections of this chapter. It is clear that no pattern of organizational arrangements can simultaneously meet all the criteria the panel would wish to suggest. We have noted, for example, that new assessment mechanisms must be close to the center of political power so that they may be influential in major decisions bearing on technological change; yet such mechanisms must maintain the image and substance of political neutrality so that the integrity and credibility of their evaluations will not be impaired. We have observed, too, that new mechanisms for technology assessment must be concerned with matters of current urgency; yet, unless such mechanisms maintain a longer time horizon than do most government organizations, their preoccupation with problems that are momentarily highly visible may lead them from crisis to crisis without the continuity of attention and action necessary for sustained progress. Thus the whole technology-assessment process could become little more than an exercise in futility.

Clearly, any institutional arrangement that is finally established must involve some compromise between these kinds of considerations. *It is especially important, therefore, that any system we propose be conceived in the most flexible terms, with the possibility of restructuring its agenda and modifying its procedures, its assumptions, and even its location within government, as it learns from experience.* Special care must be given to a continuing evaluation of the system's operation and impact, as viewed not only from within but also from the perspectives of independent critics, with direct feedback from such evaluation to the system's internal design. There must, in short, be a built-in capacity for self-renewal.

Having thus emphasized the tentative character of all that follows, we turn to the components of an organizational pattern that seems to the panel to be worthy of serious consideration.

EXECUTIVE

We have indicated previously that one component of the new mechanism must be closely linked to the President in his political capacity. An interdepartmental group, particularly one that, like the Environmental Quality Council, is composed of agency heads and established at the cabinet level, can furnish a useful mechanism for the implementation of a new emphasis, such as an emphasis on environmental protection, throughout the executive branch, so long as that new emphasis remains high among Presidential priorities. Once its mandate fades from the spotlight of Presidential concern, however, an interdepartmental council tends to operate through subordinate officers with little influence over the policies of their respective agencies, officers who may in any event be too committed to specific technology-related missions to provide the necessary neutrality.

More promising for technology-assessment purposes, both in terms of detachment and in terms of continuity, might be a high-level staff operating on the model of the Council of Economic Advisers, serving the President and answerable directly to him. But the inherent difficulty of separating the kinds of issues that such a council would have to consider from those for which the President's Office of Science and Technology bears responsibility argues strongly for merging the executive component of the new system with an appropriately expanded version of that Office. Moreover, and apart from the fact that science-policy issues are inextricably intertwined with one another and with issues of technology assessment, it seems clear that the individual or individuals in charge of whatever new activity is established within the Executive Office of the President must themselves be scientists, or at least persons with high credibility among scientists and engineers. Individuals of this sort would probably be easier to place within the Office of Science and Technology or a comparable entity than outside it. The panel is therefore agreed that the Office of Science and Technology, once its resources and responsibilities have been appropriately expanded, will provide a natural focus for any new technology-assessment activity to be established in the executive branch.

There remains a difference of view within the panel as to whether the enlarged assessment responsibilities of the Office of Science and Technology should be centered within a new Technology Assessment Department in that Office or should be distributed within the expanded Office of Science and Technology along other lines. In the former case, the new department would be placed under the direction of a Deputy Director for Technology Assessment, serving immediately under the President's Science Adviser: in the latter case, staff and resources would be significantly expanded, but no new deputy directorship would be created.

However the effort might be organized, the internal operating responsibilities of the broadened Office of Science and Technology would include the last four of the eight functions enumerated earlier: direction of an information-management system for technology assessment, preparation of an annual report, initiation of conferences and symposia, and preparation of in-house policy papers. The Office, or its Technology Assessment Department if one were established, would also operate in close cooperation with a new Technology Assessment Division within the National Science Foundation, appropriately expanded to accommodate the new responsibilities that such a division would undertake. This new division, which should report at a fairly high level within the Foundation, would be authorized to perform the first four of the eight functions enumerated earlier—that is, to administer a program of contracts and grants to outside organizations for specific assessments and for developing new conceptual tools and criteria for assessment.

The panel envisions that the Technology Assessment Division of the National Science Foundation, by prior agreement with the Office of Science and Technology or its Technology Assessment Department, would commission specifically defined assessments under contract. Each contract should be made with whatever agency or institution is judged most competent to perform the required study, whether another government agency, a professional association, a research institute, or an industrial group. Contracts could be concluded either on a "sole source" basis or by competitive bidding, but the competitive process should be employed primarily to select the best problem definition and the most promising approach rather than to produce results at minimum cost. Studies and reports prepared under contract would be subject to review prior to publication by the new assessment entity. If a report were considered to be of poor quality, its publication might be withheld. Whenever it chose to release a report, the Office of Science and Technology would have discretion either to assume responsibility for the contents of the product or to disclaim such responsibility, explicitly stating in each case which of these alternatives it had selected.

The National Science Foundation's Technology Assessment Division would also administer a grant program, through which it would support unsolicited proposals from universities, independent scholars, non-profit organizations, and public agencies. Emphasis would be placed on the work of academic groups, but other capable organizations would not be excluded. The selection of proposals for grant support would be based on the relevance of a proposed study to issues high in the priorities of the Office of Science and Technology or its Technology Assessment Department; the possible significance of the study for future policy or for the development of assessment doctrine; the scientific originality of the proposal; its general intellectual merit; its technical feasibility; the record of previous performance of the potential grantee; the expertise of the grantee's proposed investigators; and the ethical implications of any proposed experiments. The perspectives of several related disciplines should be involved, but interdisciplinarity should not be promoted as an end in itself. There should be review by peer judgment, but the grantee should be fully responsible for the intellectual content of any completed report or study, with no censorship whatever by the supporting agency.

An important purpose of the grant program would be to identify new problems and issues, particularly those not yet politically visible or not yet widely recognized in various professions. Even proposals too poorly framed or ill-conceived to be worth supporting might serve to alert assessment institutions to new kinds of dangers or to opportunities not previously considered, or might highlight the importance of questions formerly too low on the agenda of such institutions to receive sufficient attention. The panel believes that a grant program of this sort is indispensable if new assessment entities are to serve an "early warning" function that transcends habitual assumptions and momentary priorities. The grant program, moreover, would serve as a channel of inputs from the broadest possible technical community and would stimulate thinking throughout that community about the higher-order effects of technological development and the conceptual bases of technology assessment.

Since the whole concept of technology assessment is not yet well defined, the National Science Foundation's Technology Assessment Division might initially receive few worthy proposals. Growth of the program should be carefully controlled in relation to the quality of the proposals submitted, with close retrospective review of the merit of work completed. Initially, the contract program would probably be much larger than the grant program, but we would expect this situation to reverse with time. The total budget of the new assessment

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operation in the executive branch might ultimately reach the order of $50 million, with about 20 percent being spent "in-house" and 80 percent in the contract or grant program, including contracts and grants with other government agencies.

Many of the assessment studies currently carried out by committees of the National Research Council under contract with specific government agencies and by other quasi-public groups under similar arrangements might in the future be supported under the technology-assessment program here described. This would be particularly valuable for studies on issues of considerable significance for national policy, in which the present supporting agency has an interest in a particular outcome—such as a Federal Aviation Agency-supported study of the sonic boom, a Department of Defense-supported study of the ecological effects of the military use of defoliants, or a Department of Agriculture-supported study of the role of fertilizers in contributing to lake pollution and eutrophication. Existing agencies would not, of course, be precluded from supporting similar studies. The important point is that the sources of funds to support extensive assessments would no longer be limited, as they are today, to agencies that are proponents of the technologies being assessed or crusaders on behalf of particular segments of the environment.

CONGRESSIONAL

As we noted earlier, another component of the new assessment mechanism must be linked closely to Congress. Although continued reliance on existing substantive and appropriations committees to provide the required bridge is a theoretical possibility, it is the panel's view that such reliance would miss the real point of congressional involvement in the new technology-assessment institutions we propose. We have observed elsewhere that it is only in the executive agencies and in private organizations that the required broadening of assessment criteria and the needed readjustment of assessment priorities can ultimately be effected. But executives and entrepreneurs who might be disposed to bring about the necessary shift in perspective will find it exceedingly difficult to do so unless there is a significant alteration in the present play of forces in the private sector and in the executive branch.

At least with respect to technologies sponsored by executive departments and agencies, which comprise the bulk of our present concern, it can hardly be assumed that adequate pressure for alteration of perspectives will come from the Executive itself (*51*), although the Presidency, as opposed to the executive bureaucracy, can obviously serve as a crucial source of altered criteria and priorities. In part, added pressures may make themselves felt through the judiciary: as the lawsuit arising out of the Santa Barbara oil spill (*52*) and the threatened suit by Howard Hughes against the Atomic Energy Commission (*53*) suggest, litigation may occasionally supply new incentives. But the litigation mechanism is largely retrospective and sporadic, and is today of little use where either causation or damage or both are highly attenuated.

The major source of pressure that remains is the Congress. And it is precisely because public concern and criticism, channeled through Congress, can serve as the catalyst for the changes we think necessary that we view congressional involvement as indispensable. But the existing system of specialized committees, riddled with rivalries and fragmented by jurisdictional divisions, cannot be relied upon to provide the focus without which public concern is just so much undirected energy. Somehow Congress must give shape to that energy and aim it coherently toward key points of decision in executive departments and private firms, and that is precisely what the present committee system is least capable of doing. Even if that system could serve as an adequate base for technology-assessment activities directly pertinent to pending congressional legislation—something history tends to disprove—it could not serve as an adequate platform for pressure directed toward the crucial centers of decision outside of Congress with respect to technological change.

Something more than the existing committee system, therefore, seems necessary. An institutional arrangement should be devised that will:

> Provide, within or close to the Congress, an effective public forum for responsible assessment activities of individuals or groups operating outside the present governmental and industrial technology-assessment apparatus.
>
> Allow the Congress effectively to utilize the input of data, complaints, and suggestions pertinent to technological development or its consequences that may be expected to flow from the general public, in part spontaneously and in part under stimulus.
>
> Enable the Congress to make constructive and systematic use of existing assessment systems in the government, with special emphasis on the identification of gaps in information and analysis with respect to ongoing or proposed federal programs directly influencing major technological applications.
>
> Enhance the comprehensiveness and competence of technology-assessment activities engaged in by the staffs of congressional committees or by other groups responding to requests from members of Congress, by developing in Congress a greater capacity to mobilize independent professional resources to assist it in technology-assessment tasks.

Strengthen the ability of Congress critically to review findings, recommendations, and decisions potentially bearing on federal policy with respect to technology, whether made by existing executive departments and agencies, or embodied in the reports of the proposed addition to the Office of Science and Technology, or reflected in studies submitted to the proposed Technology Assessment Division of the National Science Foundation.

Equip Congress with a mechanism for generating conclusions of its own bearing on technology-assessment issues and priorities, supported by a systematic search of current professional literature and by continuing contacts with professional groups.

In order to accomplish, or even approximate, these objectives, new technology-assessment institutions linked to Congress will have to be furnished with mechanisms enabling them:

To enlist the aid of outside organizations, either directly or through the expanded National Science Foundation, in obtaining specific assessments and developing new assessment tools and criteria.

To utilize the information-management system developed under the aegis of the proposed technology-assessment operation in the Office of Science and Technology, or, conceivably, to establish a second such system.

To obtain on request from executive agencies data bearing critically on technologies supported or regulated by them.

To organize congressional hearings upon, and assist in the formulation of recommendations with respect to, assessment activities conducted in various parts of the government.

To review and comment upon all technology-assessment studies, policy papers, and reports released by the Office of Science and Technology or its Technology Assessment Department.

To file reports on their own initiative, perhaps including a congressional analogue to the previously described Annual Report on Technology Assessment to be prepared within the Office of Science and Technology.

The congressional component we envision might take either of two primary forms:

Joint Committee

The new congressional activity might be centered in a Joint Committee on Technology Assessment, equipped with a small but varied and highly qualified professional staff. To minimize the risk of domination by a single powerful individual, it might be desirable to consider a system of rotating chairmen. The committee's relationship to the proposed technology-assessment entity in the executive branch might be analogous to the relationship of the Joint Economic Committee to the Council of Economic Advisers, or analogous to the relationship of the Joint Committee on Internal Revenue Taxation to the Department of the Treasury. Like the Joint Economic Committee, the new Joint Committee on Technology Assessment would review the work of a most influential component of the executive advisory apparatus; like that committee, it could elevate the exploration of issues within its jurisdiction to a high standard of professional competence throughout the Congress; and, like the Joint Committee on Internal Revenue Taxation, the new joint committee would be charged with oversight responsibilities with respect to operations and legislation and would be entrusted with important powers and duties of investigation and systematic review. As we envision the new joint committee, it would set its own agenda and define its own priorities, rather than automatically pursuing projects proposed from outside or routinely following the priority schedule adopted by the assessment entity in the Executive Office. We contemplate giving the Joint Committee on Technology Assessment no jurisdiction over specific legislation or appropriations, but we emphasize that the result of this choice might well be to give the new committee a charter far broader and more difficult to circumscribe than would otherwise be the case.

Provision could perhaps be made for the committee to administer directly an information center and programs of contracts and grants like those already proposed for the Executive Office operation. But if it were thought that information-management systems and programs of extramural studies on the scale here contemplated would be too large for direct administration by a congressional committee, reliance might be placed instead upon the proposed technology-assessment information system in the Office of Science and Technology and the suggested Technology Assessment Division of the expanded National Science Foundation, which would then administer programs of contracts and grants both for the Office of Science and Technology and for the Joint Committee on Technology Assessment.

Congress-wide Mechanism

The new congressional activity might instead be centered in a separate Technology Assessment Office serving the Congress as a whole. As we envision such a Congress-wide mechanism, it would execute assignments of responsibility given it by the Vice President, the Speaker of the House, or the chairman of any interested committee of Congress. Unlike the Legislative Reference Service and Legislative Drafting Service, it would not be subject to requests for work by individual members of Congress. Its powers and duties would parallel those already suggested for the Joint Committee on Technology Assessment; and, as in the case of the Joint Committee, it could either administer its own programs of information management and extramural studies or rely upon the new technology-assessment structure in the executive branch to administer those phases of its work.

Although the Technology Assessment Office could be headed by a commission rather than a single director, such an arrangement might too easily lead to internecine political and doctrinal strife. It seems preferable, therefore, to organize the mechanism under the leadership of a single director. Given the complexity of arranging for the appointment of such an individual by Congress as a whole and the advantages of involving the President in the choice, the director might well be appointed by the President, by and with the advice and consent of the Senate, for an appropriate term of years, perhaps (though not necessarily) chosen to straddle rather than duplicate the term of the President himself, as in the case of the President's Science Advisory Committee, in order to provide a measure of insulation from Presidential politics. For the same reason, the director should be removable only by a concurrent resolution of both Houses of Congress.

Both the director and his staff should be compensated at sufficiently high rates to make it possible to attract first-rate men. The staff should include representation from a variety of scientific and non-scientific disciplines; its size might be similar to that of the staff of the Joint Committee on Internal Revenue Taxation—approximately fifteen professionals, some senior, some junior.

The panel is not prepared to recommend a choice as between a Congress-wide unit and a joint committee. The latter might more readily achieve the prominence, political visibility, and public access that the technology-assessment function in Congress requires. A Congress-wide organization such as the Legislative Reference Service, however skillful and conscientious, might be politically colorless to the point of ineffectuality in major areas of controversy. And such an organization might develop an excessive tendency to accept the broad political assumptions under which technological decisions are made—precisely the assumptions that a joint committee would be prone to question in depth.

On the other hand, the very political associations from which a joint committee would draw its strength and its capacity to focus attention on key issues could dangerously subvert its integrity. Although we have considered a rotating chairmanship as a conceivable antidote to this sort of risk, we recognize the obstacles to such a proposal and realize that a Congress-wide entity might be preferable from this perspective. Such an entity, moreover, might be more responsive to the diverse and pluralistic character of the problems it would be required to address. The process of technology assessment is so broad and varied in its reach that it touches the concerns of a great many different congressional committees. It might prove difficult to devise a procedure whereby other committees could make effective use of a Joint Committee on Technology Assessment without overloading it with requests that it would be less capable of rejecting than would a Congress-wide mechanism. And, even if an acceptable interface with other committees could be designed, it might be a mistake, in terms of both the job to be done and practical congressional politics, to suggest that responsibility within Congress for technology assessment be concentrated in a single committee. From this viewpoint it might be thought more realistic, and more consonant with the need of Congress to continue the progressive evolution of its own organization and procedures, to provide a new Congress-wide mechanism that will serve all the relevant committees through their respective chairmen. Given the powerful considerations favoring the joint committee, however, the choice becomes a very difficult one. In the final analysis, of course, Congress itself will have to decide which approach to take.

There is yet another matter on which the panel is unprepared to offer any precise recommendations. Although the panel is in essential agreement that there must be a new locus of technology-assessment activities both in the executive branch and in Congress, there remains some difference of opinion as to how responsibilities and resources should be allocated between the executive and congressional branches of the activity and where the greater weight should lie. A congressional base would be better suited for educating the public on the issues and ensuring representation of the widest possible range of interests. Moreover, many technology assessments may result in new or amended legislation or in the restructuring of government organization or of congressional committees in response to technological change. Much can therefore be said for having Congress intimately involved throughout, since it is the views of congressmen and of their affected constituents that will ultimately determine the fate of many important policy recommendations emerging from assessment activities. On the other hand, congressional institutions have not traditionally provided an effective base for highly professionalized activities or for extensive contractual relations with private organizations. The mere magnitude of the funds involved may argue against direct congressional management. Institutions serving all of Congress have tended historically to be understaffed and overworked. They have often felt constrained for political reasons to respond to the request of any legislator, regardless of their own evaluations of the significance of the issue. Thus they have retained little control over their own priorities and over the definitions of the problems they have addressed. Since, in the panel's view, one of the most essential functions of new technology-assessment institutions will be to establish priorities among problems for attention on a basis more objective than "the squeaky wheel gets the grease," centering the activity in a congressional body may cause serious difficulties.

A center of gravity in the executive branch would tend to ensure a more professional and continuous operation, one that would almost certainly enjoy greater credibility among scientists and technologists—an important matter if assessments are not be be sabotaged, consciously or unconsciously, by the tyranny of small decisions (*54*) made primarily by technologists themselves. On the other hand, the weakness of an executive agency in this area is that, while it may do its job with greater technical competence within a fixed framework of assumptions and criteria, it may do a poorer job of examining the assumptions or changing them. Even an executive agency that is relatively free from operational responsibilities and direct decision-making powers with respect to specific projects must be responsive in some measure to "the President's Program" unless it is established as a quasi-independent body like the Federal Reserve Board, a possibility to be considered below. Finally, an executive agency may be less inclined than its congressional counterpart to listen sympathetically to all the many affected constituencies.

To some extent these competing considerations can be accommodated by an imaginative sharing of responsibilities between the executive and congressional components of the assessment activity. Thus the research and information-management elements of the activity might be centered in the executive unit while the educational and participatory elements might be centered in its congressional counterpart. The panel recognizes, however, that difficult choices of emphasis will have to be made, and, with respect to such choices, the panel has agreed to disagree. We would insist only that the balance not be tipped completely one way or the other—that is, that both a congressional and an executive agency should play *some* role in the assessment process—and that on the congressional side this role should be embodied in some mechanism that lies outside the present structure of specialized committees.

INDEPENDENT

There remains the possibility of a new technology-assessment entity separated from both of the political branches, much as the quasi-independent commissions and boards are separated today. The chairman of such an entity would presumably be appointed for a fixed term by the President but could be removed neither by him nor by Congress except for cause and after a full hearing. Such an institution might be contemplated as an addition to the Executive Office structure proposed above, in which case it could serve simply as a substitute for a Congress-wide mechanism, or it might contain internal divisions for information management and the administration of contract and grant programs, in which case it might approximate a self-contained Technology Assessment Board, supplanting the unit in the executive branch as well as the unit in the Congress.

It might be thought that this sort of separation would possess certain advantages. Thus an entity removed from Congress and supposedly freed of the momentary parochial concerns of local and state-wide constituencies might find it possible to take a broader view than any likely to emerge from a congressional mechanism, while an entity removed from the Presidency and theoretically liberated from the pressures of the executive bureaucracy and the momentum of the Presidential personality might be able to steer a more objective and daring course than any likely to meet the approval of a mechanism in the Executive Office. Yet, for the reasons developed earlier, the panel regards the image of a totally apolitical assessment mechanism as highly unrealistic. Moreover, to the seeming advantages of insulation from political influence there correspond the grave disadvantages of weakened access to political power; to the apparent benefits of detachment from narrow constituencies there correspond the high costs of inaccessibility to a concerned public; to the arguable gains of protection from executive perspectives there correspond the serious losses of separation from the wellsprings of federal science policy. On balance, therefore, the panel considers the mechanisms whose formation we have recommended in the executive and legislative branches to be distinctly preferable to an independent or quasi-independent assessment body.

Military Technology

The area of military technology has not received major attention in the panel's deliberations. Yet this area accounts for more than half the resources devoted by the federal government to research and development. In discussing the impact of technology on our society it is, in a sense, absurd to exclude consideration of military technology, for its dynamic development in competition with other nations determines much of what we do in technology assessment.

Plainly, the exploitation of military technology has a major impact on our environment and on our future options. The continuing arms race affects the security not only of the world super-powers but also of the rest of the world's people, vast numbers of whom would suffer from a thermonuclear exchange between the major powers. The environmental effects of a possible military conflict, and indeed of the arms race itself, can less and less be confined to the battleground or even to the political units and people immediately engaged.

Yet military technology is unique in several respects. In the first place, despite growing concern in Congress and elsewhere, military technology remains much less publicly visible, relative to its importance, than other technologies and much less subject to full discussion and debate in a public forum. A considerable proportion of the technological data is either classified or proprietary, and the controls over its flow are essentially in the hands of the proponents of technological innovation in the military sphere. Furthermore, the environment in which military technology is developed is strongly conditioned by the interpretation of intelligence information, which is even more highly controlled and sensitive than is information about military technology itself. Crucial arguments concerning whether or not to go forward with a new military technological development often involve information that is not available to the public or is subject to controlled release to the public in such a way as to support particular policy viewpoints. Finally, during the period of the cold war, national security has enjoyed such overriding priority that the secondary consequences of military technology have tended to receive even less consideration than have those of other technologies. It has been relatively easy to disarm the critics and the skeptics both inside and outside of government, both as a result of military or semi-military control over information sources, and in consequence of a general public attitude that military technology is too crucial to challenge or too complicated to understand.

The panel does not propose to pass judgment on military technology or on the decision-making mechanisms regarding it. Our remarks concerning the proponents' control of crucial information for technology assessment are not intended to suggest that the proponents of military technology have used this control irresponsibly or to the detriment of the larger public interest, although a growing number of people believe this to be the case. We wish simply to point out that the present system for the assessment of military technology violates most of the canons suggested by the panel with regard to the representation of affected interests, the consideration of larger social and environmental contexts, the maintenance of future options, and public visibility and review of the crucial information and arguments.

Many of these limitations in the process of technology assessment for the military may be essential to national security, but the panel would be remiss in its responsibility if it did not point out what appears to be almost the most glaring gap in our present technology-assessment mechanisms. The significance of this gap becomes even clearer when one recalls that the prior development of military technology often serves as a channel for the introduction of new technology into the civilian market, as in the case of computers, jet aircraft, and nuclear reactors. Under such circumstances there is a tendency for the relatively loose assessment criteria established under the urgency of national security to be transferred more or less automatically into the field of civilian applications. Assumptions and biases created under military auspices become much more difficult to modify under the civilian aegis because of the vested interests built up in the process of satisfying military requirements.

These observations suggest the possible inclusion of some mechanism for technology assessment in classified areas—a mechanism utilizing people who are not directly responsible for national security matters. Creating such a mechanism would require an extension of the concept of "need to know" beyond those immediately involved in the promotion of national security as defined in military terms. One would wish to incorporate more institutionalized criticism into the decision-making process for military technology—criticism designed deliberately to broaden the criteria of technology assessment well beyond the strictly military context. Unless this is done, there is a real danger either of great social or environmental damage, or, conversely, of a broad public reaction against all forms of military technology, which might endanger the security position of the United States.

CHAPTER VI. SUMMARY AND CONCLUSIONS

The members of this panel are persuaded that mechanisms for technology assessment beyond those currently operating are clearly needed. Although technology-assessment activities are already widely dispersed among government instrumentalities and private organizations, it is our conclusion that such activities suffer in their totality from basic inadequacies that will prove increasingly critical as the scale and intensity of technological development continue to mount.

Our study has revealed that existing mechanisms, whether they involve government agencies, private industries, or professional groups, possess intrinsic limitations, some structural and others psychological, that leave serious gaps in the spectrum of processes that assess and direct the development of technology in our society: In the formulation of issues for assessment and in the attribution of value to alternative outcomes, those processes too often ignore the broader social and environmental contexts in which their effects are felt. In the calculation of costs and benefits, they ascribe too little significance to the preservation of future options. They give too little attention and support to research and monitoring programs calculated to minimize technological surprise and to deal more rationally with the burdens of uncertainty. They frequently reflect the views, interests, enthusiasms, and biases of unduly narrow constituencies and create insufficient opportunities for meaningful public participation in choices having major public consequences. And they manifest too little concern

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for the evolution of consistent principles in the formulation and enforcement of assessment criteria.

The reasons for these shortcomings are complex and varied. In part, the difficulties are conceptual—inadequacies in analytic tools and in theoretical understanding; failures of imagination; deficiencies of data; the sheer technical difficulties of perceptive and precise evaluation. In greater measure, the problems are institutional—economic, legal, or political constraints upon the interests that each individual decision-maker is encouraged to treat as his own; limits upon the representation of varied interests in collective processes of decision; constraints upon the coordination and focusing of pertinent efforts. These difficulties cannot be overcome at a single stroke; but they can gradually be reduced by a program of technology assessment that is broader in fundamental conception and scope than any now existing, one that takes into account the changing values, sensitivities, and priorities of society.

The present organization of private and public assessment systems is too fragmented and uncoordinated, too lacking in professionalism, continuity, and detachment, to provide a viable institutional basis for the support of the research and education that a sufficiently broad technology-assessment program will demand and for the development of the professional competence and vision that such a program will require. No institution or group of institutions is today charged with the responsibility, or equipped with the resources, to review the criteria and assumptions, monitor the operating procedures, and integrate the findings, of our many technology-assessment efforts—even those undertaken within the federal government—or to stimulate the development of a set of coherent principles that might increase the quality and influence of such efforts and enhance their sophistication.

Although we recommend the creation of new institutions in the federal government to perform these integrating functions of review and stimulation, we acknowledge that the present multiplicity of technology-assessment processes is both desirable and necessary. Technological development pervades so many aspects of contemporary life that no limited number of organizations devoted to technology assessment could competently span the enormous range of relevant activities. Thus we do not contemplate in this report or foresee in the future a highly centralized process of technological evaluation, even for the areas of technology that are largely dependent upon federal programs and policies. Such centralization would be not only unworkable but unwise, politically unacceptable, and extremely dangerous. Thus new institutions are needed not to supersede existing mechanisms but to supplement them.

With these principles in mind, the panel urges the creation of a constellation of organizations, with components located strategically within both political branches, that can create a focus and a forum for responsible technology-assessment activities throughout government and the private sector. Limited at the outset to those areas of technology that are strongly and directly influenced by federal policy, such organizations must be separated scrupulously from any responsibility for promoting or regulating technological applications and must have the authority and resources for:

1. Undertaking substantial in-house studies to evaluate trends in technology and in technology-assessment practices; to examine the operations of existing assessment mechanisms; to establish priorities for technology-assessment efforts; and to derive policy alternatives and recommendations from research.

2. Supporting major research activities in external organizations with respect to technical issues arising in the course of specific assessments and theoretical issues pertinent to the improvement of the intellectual base for technology assessment in general.

3. Encouraging activities and programs related to the stimulation of public awareness of, and interest in, assessment issues and the education and development of professional groups with broadened perspectives to staff future technology-assessment activities in industry, in government, and in other institutions.

It is the panel's hope that, out of a set of mechanisms capable of performing these functions, there will evolve a consistent and influential body of assessment principles, derived not only from conscious attempts to formulate general policy but also from experience with individual cases selected in part for their precedent-setting potential. Although limited at its inception to federally supported or regulated technologies, the program we envision could, over time, inspire parallel efforts at other levels of government, from the local to the international, and in the private sector as well.

However our specific recommendations might be viewed, the members of this panel are convinced that *some* form of constructive action is imperative and that such action cannot be long delayed without greatly increasing the difficulty of its implementation and significantly diminishing the prospects for its success. The future of technology holds great promise for mankind if greater thought and effort are devoted to its development. If society persists in its present course, the future holds great peril, whether from the uncontrolled effects of technology itself or from an unreasoned political reaction against all technological innovation.

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APPENDIX A

Structuring the Tasks of Assessment and Response

The Panel presents here discussions of technology assessment relative to different foci, or starting points—technology itself, society, the environment, the individual—and to different modes of assessment and of responses to it.

The political system, which provides the frame in which any realistic analysis of technology assessment must be set, cannot be expected to react intelligently to an unstructured mass of issues and problems somehow related to implications of technological development. One of the obstacles to appropriate action is the lack of any effective structuring instrument. Even if there could be set in motion a system capable of truly comprehensive assessment and mature response, it would be necessary to decide how the energies of such a system ought to be allocated among the virtually limitless range of issues that might be brought to its attention. Without some rational way of making that sort of decision, priorities in the processes of assessment and response, as we noted in the body of this report, would tend to be set by accident or by the political muscle of interested groups rather than by the urgency of any given problem. Without effective criteria for ascribing priority to assessment issues, therefore, the system would be unlikely to focus attention on the critical questions when they are truly ripe for decision.

But the evolution of such criteria will require the development of better models than can now be summoned to the task. It will be necessary, for example, to explore alternative ways of classifying technological developments and their effects, of categorizing types of assessment and methods of response. Only with the aid of more sophisticated taxonomies for such purposes can one begin to understand the complex dynamics of the processes involved; only through such understanding can one formulate and evaluate crucial policy alternatives.

There is, of course, no unique way to break down so vast a subject into components that are at once useful and manageable. In our own deliberations, however, we have found it helpful to conceive of this complex area in terms of three interrelated "blocks": focal points for assessment; assessment modes and mechanisms; patterns of response and action.

Possible Focal Points for Assessment

We have found it useful in our discussions to distinguish among assessment efforts in terms of the points in the system from which they begin: (1) technology, (2) society, (3) the environment, (4) the individual, or (5) some combination of the preceding.

TECHNOLOGY

The first general approach begins from a particular technology or cluster of interrelated technologies and seeks to explore the possible consequences of contemplated, ongoing, or alternative trends in the area under consideration. In this context a technology is thought of as more than hardware. It is perceived as a system of interrelated innovations, some technical and some social, which comprise some sort of coherent nexus pertaining to the systematic manipulation of the environment. From this standpoint, for example, "the automobile" would include the manufacturing process, the system of dealers and service stations, the highway program, urban traffic control personnel and facilities, relevant rules and principles of tort law, liability insurance schemes, and so on. In terms of the distinction made in the introductory chapter, the focal point for assessment within this mode might thus be either some component of the technology or some component of its supporting system.

Assessments focusing on technology might be further sub-classified in a wide variety of ways. With respect to supporting systems, for example, a distinction might be drawn between (a) assessments that focus upon the economic, social, or legal arrangements *facilitating* the introduction, acceptance, distribution, or use of a technology (for example, foreign-aid programs supporting agricultural or hydroelectric technologies in developing nations; or community health-care-delivery systems; or governmentally supported medical insurance; or community-antenna television systems (CATV); or municipal fluoridation of water), and (b) assessments that focus upon the arrangements that *constrain* such introduction or use, impose obligations upon the user with respect to compensating injured persons, or otherwise seek to overcome the potentially deleterious consequences of uninhibited application (for example, licensing the use of radio-isotopes; or requiring judicial warrants as a prerequisite to lawful electronic eavesdropping; or compelling prior registration and approval of new drugs; or requiring batch-testing of antibiotics; or imposing a tax on environment-deteriorating activities; or enforcing air and water quality standards at the source).

With respect to technological systems, a distinction might be made among (a) those assessments that focus on the *advance of a technology* from the earlier stages of research and development to the later stages of introduction (for example, an evaluation of current progress in weather-modification technology); (b) those that focus on the *transfer of a technology* from one area of application to another (for example, adoption of military jet engines for civilian use; or application of satellite surveillance to earth resources; or use of particle accelerators for cancer therapy or food preservation); and (c) those that focus on *growth in the scale of a given application* (for example, proliferation of DDT or of tetraethyl lead antiknock compounds; or wider usage of oral contraceptives; or growing sizes of oil tankers or trucks).

Distinctions for assessment purposes might also be drawn in terms of the *availability of intermediaries* or buffers between the technology and its users—as in the case of medicine, where doctors and hospitals act as intermediaries in the use of prescription drugs; or in the case of construction, where architects may serve as intermediaries for at least some new techniques. In many situations, the availability of such intermediaries, as assessors in their own right, might make governmental intervention somewhat less urgent. Yet the proliferation of choices open to professionals makes individual assessment less and less reliable, a fact that accounts for the need to interpose the Food and Drug Administration between the drug manufacturer and the physician or hospital, or the building inspector between the supplier of building materials or equipment and the architect.

Or technological developments might be distinguished in terms of expected *lead-times* (computer-aided instruction or organ transplants, for example, have shorter lead-times than, say, repair of genetic defects) or in terms of how radical a *departure* they seem to represent, noting (as we have earlier) that it is particularly important to beware of false analogies with predecessor technologies.

Technological developments might also be categorized in terms of *visibility*. For such purposes, it would be important to determine to what extent the dimensions of a given development are exposed to public scrutiny rather than either deliberately concealed (as in the case, for example, of many military projects) or difficult to discern because of their dependence upon uncontroversial, incremental decisions made by a multitude of diverse investors or innovators (*1*).

A distinct but related classification might be made in terms of *economic concentration* of producers (though not necessarily of consumers). In a number of areas, such as power reactors, jet aircraft, large-scale weather modification, or space communications, technology is characterized by a few massive applications, usually supported in their earlier stages with public funds involving fairly explicit political decisions. Although market forces eventually tend to take over as any technology matures—witness, for example, satellite communications and power reactors—highly concentrated investment at the outset may make it easier for comprehensive and timely assessments to be made and for their results to prove influential than in cases in which the original investments are made in such small packages and are so widely dispersed that no comparable "handle" is initially available, requiring one to rely on less direct methods of control. With respect, for example, to automobiles, television, transistors, computers, or agricultural machinery, one begins to notice significant effects only after widespread introduction and use. In such areas, moreover, application is ordinarily governed from the outset less by collective action than by individual market decisions not readily subject to political control. Even in such areas, of course, government action may alter the incentive structure, and public decisions (for example, highway construction in the case of the automobile; licensing and frequency allocation in the case of television; fall-out from public investment in military and space technology in the case of transistors and computers; public investment in agricultural research, the extension program, and price supports in the case of farming) strongly influence the evolution of technology. Although the distinction between technologies with intensive economic concentration and those in which investment tends to be more diffuse is thus not as sharp as might at first appear, it seems useful nonetheless to note the difference for assessment purposes.

Perhaps a more basic phenomenon requiring exploration is the degree to which the decision-making processes influencing a given technological development are *centralized* and hence subject to explicit collective control. The primary relevance of economic concentration for our purposes is that it tends to assure such centralization in the early stages of technological development. Susceptibility to public control, however, may often be more a function of visibility than of centralization or economic concentration. The area of organ transplant technology, for example, is sufficiently "open" that public policy can make itself felt directly, despite the fact that activity and investment in that area are widely dispersed and anything but intensively centralized.

For purposes of classification it may be useful also to remember that the course of a technological development and the difficulties of its assessment and control depend strongly upon where it *originates*, what *forces* generate it (domestic profit motive versus concern for national power or prestige, for example), its *competitive environment*, and the *sources of resistance* to its advance—political, social, legal, economic, or religious (for example, the pill). As we have already noted, it is difficult to generalize about where vested interests will be aligned with respect to a new technology. Often those interests press for the adoption of technology; not infrequently, however, they oppose it. Failure to develop needed technology, as in low-cost housing, traffic control, or high-speed ground transport, is often the consequence of vested interests having accumulated around the continuation of older ways of doing things. It might, indeed, be useful to classify technological developments with respect to the relative power and cohesiveness of their *proponents* and *opponents*, respectively, and of such *third parties* as have become (or may become) involved in the decisions that will influence their evolution.

Although the following classification partly overlaps several of those previously suggested, the panel has found it useful to separate those technological developments that are very substantially influenced by *federal activity*, either supportive or restrictive, from those with little or no immediate federal involvement. Federal responsibility for assessment and control seems clearer in the former areas; opposition in the private sector to such assessment and control is likely to be less intense; and the ease with which it is possible to minimize the undesirable secondary consequences of a new assessment activity is surely greater in situations in which a federal "handle" is already present. Because of the dominance of the private market it is easy to forget the crucial role played by federal actions and policies in the development of such technologies as automobiles, television, and air transport. Thus the federal "handle" is much larger than is often thought.

An attempt might finally be made to classify technologies in *functional* or *operational* terms that facilitate generalization about the ease with which they can be assessed or regulated. Thus, for example, technologies might be classified according to their operation as ways of either transforming, transporting, or preserving either matter, energy, people, information, or some other aspect of the environment (*2*). An effort could then be made to classify the kinds of effects characteristically associated with each of these categories. Perhaps a classification in terms of the characteristics of the relevant *industry* rather than the intrinsic characteristics of the technology would be useful. In both the communications and energy industries, for example, the time horizon for planning is relatively long and government regulation is especially influential. These characteristics tend to facilitate more thorough and critical assessment, as does the fact that these industries sell functions rather than products and are thus better equipped to examine alternative technologies to achieve parallel purposes.

SOCIETY

An entirely different focal point for technology assessment is suggested by the social-indicators movement and by related attempts to enhance our sensitivity to, and understanding of, social change. Thus, it is possible to start from a given social system (for example, housing, transportation, production, marketing, education, communication, recreation), or from some kind of social relationship (for example, employment, marriage, family, property), or from some broad distributive category (for example, residential patterns, composition of the job market, allocations of power and resources, class structure, income distribution), or from some other social aggregate (for example, population, trade balance, gross national product, military strength) and explore how the area in question might be affected by the growth and spread of various alternative technologies, including the synergistic effects among several technologies or between technologies and social or political trends.

Given the limited state of present understanding of social systems and human behavior, there is little likelihood that such explorations would lead to convincing, long-range assessments of the impact of various developments on society. But in many areas it may be possible to anticipate the medium-range societal impacts with enough confidence to make the effort worth while, at least when more has been learned about the ways in which technological change induces social change.

New technology opens new opportunities and lessens existing constraints on human activities; simultaneously, it generates problems for individuals, groups, and institutions as the new opportunities are exploited. The interactions are often distressingly complex. As a recent study has suggested, for example, "improved transportation technology and increased ownership of private automobiles have increased the mobility of businesses and individuals. This has led to altered patterns of industrial and residential location, so that older unified cities are being increasingly transformed into larger metropolitan complexes. The new opportunities for mobility are largely denied to the poor and black populations of the core cities, however, partly for economic reasons, and partly as a result of restrictions on choice of residence by Negroes, thus leading to persistent Negro unemployment despite a generally high level of economic activity. Cities are thus increasingly unable to perform their traditional functions of providing employment opportunities for all segments of their populations and an integrated social environment that can temper ethnic and racial differences. * * * The resulting instability is further aggravated by modern communications technology, which heightens the expectations of the poor and the fears of the well-to-do and adds frustration and bitterness to the urban crisis"(*3*) despite the long-term hope that improved communication networks might eventually alleviate some of the problems caused by improved transportation systems through providing practical alternatives to physical meetings.

Clearly, if understanding of phenomena as complex as these is to be acquired in time for effective action, available models of the mechanisms through which technology impinges upon society must be greatly improved. One step in the development of improved models, it would seem, will be precisely the attempt to organize at least some technology-assessment activities around the themes provided by social patterns and problems, rather than focusing exclusively upon technology itself as the central theme for assessment.

THE ENVIRONMENT

Yet another possible focal point for assessment is provided by the theme of "environmental quality." Thus it might be useful to begin with some segment of the physical environment—a particular resource ("clean" air, "clean" water, and so on) or an ecological objective, either abiotic or biotic—and then explore how such resources or goals might be influenced by possible technological developments and by alternative technological applications. It might be instructive, for example, to look at specific estuarine zones or at wilderness areas and ask how they will be affected by various liquid and solid industrial waste-disposal techniques, by proposed recreational or commercial uses, by contemplated highway programs, and so on. Or it might be interesting to focus on a broad environmental resource—the lower atmosphere, for instance—and attempt to monitor and forecast changes in its behavior and quality, whether due to technological applications or to other causes, as does the Environmental Science Services Administration (ESSA) in the Commerce Department.

In support of such efforts, environmental consequences might be divided among (a) those that are primarily *aesthetic* (noise levels, smells, atmospheric clarity, scenic degradation, and so on); (b) those that affect entire *ecosystems* (changes in species balance, water eutrophication, and the like); and (c) those that are basically

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biomedical, though too low in intensity to have other than possible long-term effects upon individual physiology or psychology (lead salts in the atmosphere or other kinds of low-toxicity trace residues, for instance) (*4*).

Or a distinction might be drawn between (a) environmental contamination that can usefully be described in terms of *residuals* (of unrecycled energy outputs, solid or liquid byproducts, radioactive wastes, and so on), and (b) more *systemic* environmental problems (urban congestion, unsightly billboards and buildings, and so on).

It should not too readily be assumed, however, that the notion of "environmental quality," even when augmented by extensive taxonomic efforts, can itself provide a very useful focus for thinking about assessment problems. Any concept that includes concerns as wide-ranging as solid-waste disposal, occupational hygiene, highway beautification, mental health, urban design, vector control, and smog prevention may be too broad to be operational. This does not mean, of course, that the mounting public concern with "environmental problems" can contribute nothing to technology-assessment activities. It means simply that, pending further attention to definitional and other basic matters, the contemporary interest in environmental issues will make its major contribution to technology assessment by providing impetus for action rather than by furnishing such action with an organizational focus.

THE INDIVIDUAL

Finally, assessment efforts might be organized around effects on the life experience of the individual—the development and socialization of the child in a world of mass media and rapid communication; the work experience of the adult and his perception of himself in relation to technological change; his access to material goods, to solitude, to human companionship and intimacy; his participation in decisions that affect his well-being; his mental health; his life expectancy; his exposure to risks of accident and injury.

Assessment activity structured in this way could be truly useful only if one had a workable classification of the diversity of interests and roles of individuals, so that the impact of a variety of technologies on specific roles could be systematically studied. It appears difficult in general to give this mode of assessment sufficient focus to provide a worthwhile basis for public decisions with respect to technology. Nevertheless, some exploratory work along such lines may be of value in identifying new problem areas for more specifically technological study. An example is suggested by recent investigations of the impact, actual and potential, of various electronic techniques and data-handling systems upon individual privacy, and the new technological means that modern electronics might offer to increase the protection of such privacy—for example, by controlling access to data files. Another illustration might be a study attempting to identify all the kinds of trace elements in the environment to which an individual might be exposed in his lifetime and to study the combined effects of such cumulative exposure on his health.

MIXED

A blend of the approaches sketched above seems necessary. Efforts that start from particular technological developments and work outward, for example, might overlook wide circles of systems effects that cannot readily be associated with any single technology. As the panel has already observed, technical innovations and their applications generate spiraling chains of derivative consequences, often dispersed in many directions and often converging with consequences originating from very distant sources. One need only witness the cluster of technological developments and social policies that converged to produce the migration to megalopolis and the decay of the central city (*5*) to realize that assessments centered on particular technological developments might miss important cumulative effects, often synergistic ones, which in the end may determine the character of the resulting problem. Even with respect to the biology of a single individual, it is a commonplace that various agents may interact to produce cumulative consequences that are in no sense limited to the sum of their individual components.

Such synergistic possibilities must be carefully explored, but they can never be explored adequately by a sequence of assessment mechanisms, each of which is geared simply to the evaluation of a single line of technological development, unless the assessments are somehow linked within a broader framework capable of evaluating each technology as part of a whole system of activities, perhaps functionally unrelated, contributing to certain kinds of effects. For example, mere competition for use of various parts of the environment may produce unfortunate effects that no one use or sum of uses could account for. Traffic problems and overcrowding are of this character. Similarly, pollution effects—lake eutrophication, for example—are often non-linear with respect to environmental load, involving a threshold beyond which deterioration becomes much more rapid and self-reinforcing. It is critical to be especially alert to potential triggering mechanisms associated with quantitative changes in environmental or sociological or psychological burdens. Assessments centered on specific technological applications are subject to important shortcomings with respect to such synergistic phenomena.

The other three approaches, starting from society or the environment or the individual and then working back to technological developments that might be expected to impinge upon the areas being explored, do not share this basic defect and are better suited to the investigation of interacting and synergistic consequences. Each of these approaches, however, has defects of its own which are not shared by the first. Assessment efforts that begin from a segment of society or of the environment may overlook new technologies altogether, or may at least overlook alternative technologies and those that might alleviate the societal or environmental defects of a technology that has been identified as significant. Moreover, starting from a sector of society or an interest or role of the individual may make it especially difficult to separate the role of technology from that of social trends or policies. Finally, starting from the individual heightens the already serious problem of weighing "social benefits" against personal risks or injuries.

Thus it seems that some elements of all four approaches are required. Indeed, it may well be that in some areas the focal point for assessment should not fall into any of these areas, but should straddle them in an appropriate way. For example, a project or policy that raises a number of technological as well as non-technological issues may be proposed, calling for a "systems assessment" that cannot be pressed into any of the above categories.

EFFECT-ORIENTED ASSESSMENT IN GENERAL

It is important to recognize that effects may be categorized in many ways other than those suggested by the social-environmental-individual categorization employed above. It is possible, for example, to distinguish those effects of technology that result from the *availability* of new options from those that result from the *exercise* of such options. The former are often overlooked. For example, the ready availability of birth control techniques, whether or not broadly employed, might have the effect of reducing the acceptability of therapeutic abortion. Or the availability of nuclear power may alter the location-price structure of conventional power and thus affect industrial location and labor migration even when not heavily applied.

In examining the effects of technological change associated with the *exercise* or *non-exercise* of the possibilities it creates, the panel has, of course, distinguished between *intended* effects (such as more efficient production) and those that are *unintended* (such as a greater number of industrial accidents, or noisier airports). The panel has also distinguished effects that are essentially *direct* from those that are truly *derivative*. The latter are often the most important, and their meaningful classification, of course, is very difficult. An effect might be called "derivative" if the chain connecting it to its technological "cause" contains a large number of manipulable, reversible, or avoidable links; or if it is the result of the confluence of several distinct "causes"; or if it flows not so much from the exercise of the technological option as from the options that are foreclosed or made more costly by such exercise (opportunity costs). In this connection it is important to keep in mind that the very act of exploiting some opportunities often makes it impossible, or at least more costly, to exploit others. A lake polluted with industrial effluents may be unavailable for recreational use; soil cultivated for one crop may become unavailable for another; the commitment to faster transportation or better communication may ultimately foreclose options of solitude and stability. In relation to both the natural environment and the social environment, such "opportunity costs" are extremely important in the total picture of higher-order consequences of technological application. In general, the panel believes that more thought must be given to the various ways in which such higher-order consequences may be generated by technological developments (*6*).

Another important distinction recurring in the panel's discussions has involved *effects upon the primary beneficiaries* of a technology versus *effects upon more remote individuals*—non-users, who are not parties to the "technological transaction." The assessment and control of effects upon primary beneficiaries, by institutions such as the Food and Drug Administration, is far simpler, of course, than the assessment and control of non-user effects. The panel has also drawn a distinction between *short-range* effects and those that make themselves felt over *longer* periods of time, often in a *cumulative* way. The latter, as we have observed, are generally harder to forecast, and harder to inject into the decision-making process, however smoothly the system may function with respect to structural externality. The panel has distinguished between *deterministic* effects and those that are basically *statistical*. Most important effects are probably of the latter variety and are correspondingly difficult to dramatize, as the experience with cigarettes, lung cancer, and cardiovascular diseases makes painfully clear. *Effects on identifiable groups* have been distinguished from those of a more *diffuse* character—effects on ecological systems, life patterns, values, and so on. With respect to securing adequate representation of diverse interests in assessment and decision-making processes, the panel has noted that the greatest difficulties arise in dealing with the most diffuse effects—those by which many persons are injured or benefited slightly as against those by which a few are affected more intensely.

Obvious, but no less important, are the *scope* of anticipated effects, the *time* and *expense* needed to appraise or alter them, and, most critical of all, their *reversibility*.

Changes in population, life expectancy, intensity of land utilization, consumption of fossil fuels or other exhaustible resources; modifications in topography (whether deliberate or inadvertent), including erosion, delta formation, silting; reduction in species diversity—effects such as these may be partially or wholly irreversible and thus are far more important for assessment purposes than are effects that can be reversed without inordinate difficulty or with the application of new technology in the future. It is important, however, not to treat a consequence as irreversible simply because it resists purposeful modification. Although the cumulative effects of environmental contamination by certain toxic or radioactive substances, for example, are difficult to reverse by deliberate means, some of these effects tend to decrease quite rapidly with time and thus cannot be deemed truly irreversible. Such considerations are particularly important in deciding the urgency of a given issue for purposes of assessment or response.

Finally, effects that are essentially *inherent in the technology* should he distinguished from those that flow only from *technological abuse.* In the former category, for example, one must probably place the sonic boom from supersonic transport. The telephone network, in contrast, presents quite different problems, since its most serious harms flow from abuse (wiretapping) rather than from any intrinsic technical characteristic, and can be largely avoided by those who are willing to make only limited and guarded use of the telephone. More generally, one must distinguish between *technological effects that can be dealt with at the option of the individual user*—for instance, protection of privacy by the use of unlisted numbers—and *those that must be dealt with by a system modification for which all users must pay*, such as an aircraft blind-landing system.

Possible Assessment Modes and Mechanisms

Implicit in much of this report has been the distinction between *internalized* assessment—that is, assessment built into the incentive structure of the decision-making process in question—and *externalized* assessment—that is, assessment conducted by an institution deliberately separated from the front-line decision-maker. There has been general agreement in the panel that internalized assessment, whenever it can be applied, is far preferable, essentially because self-regulating ("closed-loop") systems are best able to adjust to net variations within the systems themselves. Externalized assessment, like any form of absentee management, tends to separate authority from responsibility, while internalized assessment tends to redefine responsibility without separating it from authority. However, self-regulating systems may be insensitive to externalities and may have to be supplemented by externalized ("open-loop") assessment. Thus, although there are advantages to being on the scene, proximity and commitment tend to generate blind spots. In sum, any scheme devised for improving the assessment and management of technological change should make maximum possible use of internal decision-making processes and should proceed by making those processes more sensitive rather than by imposing external constraints, but should recognize the necessity for some external assessment and supervision to make the system function properly. *Ideally, the effort should be to modify goals and criteria of success without dictating the means of achieving them.*

In classifying assessment modes and mechanisms, it is possible to look at the *places from which they start*, which we have done above in exploring possible focal points for assessment. It is possible also to look at their *time perspective*—distinguishing those that are basically *anticipatory* from those that are engaged in *continuous monitoring* or those whose primary obligations center upon *periodic reevaluation*. For a great many reasons, in part because objectives and values change, all three are needed. The evolution of technology is dynamic. To be comprehensive, assessment requires an occasional snapshot of a large system at a moment in time, but to be responsive to change it must provide a continuous movie as well.

The panel has had occasion to distinguish between *negative* assessment—that is, assessment by an agency designed primarily to criticize new technology (the Food and Drug Administration, for example)—and *positive* assessment—that is, assessment by an agency responsible for exploring the value and feasibility of promoting new technology (for example, the Atomic Energy Commission, the Public Health Service, or the Department of Agriculture). Each assessment mode, as we have noted, has its characteristic weaknesses, the negative tending to be unduly conservative and the positive overly promotional. *The solution the panel has urged is a second-order assessment activity performed by an entity with neither promotional tasks nor risk-preventing responsibilities, an entity ancillary to the activities of all agencies with one or the other kind of bias.*

Another type of distinction might be made according to the extent to which deliberate public action is envisioned to influence the direction of technological change. Three distinct approaches are *projective* assessment, *evaluative* assessment, and *directive* assessment.

In the first, which most closely resembles technological forecasting, possible alternatives for the future evolution of technology are analyzed to discern the most likely pattern of evolution and to specify probable margins of error. Any such projection, of course, requires an evaluation of the effects of society (that is, market and political influence) upon technology as well as an assessment of the effects of technology upon society and the environment.

The second mode, *evaluative assessment*, most closely resembles systems analysis. It entails the study of existing or proposed programs with highly technological content to determine their internal goals and assumptions; to assess the degree to which the projected efforts are likely to achieve their stated goals; and, ultimately, to evaluate the desirability of the goals themselves, taking into account possible deleterious side-effects.

The third mode, *directive assessment*, is less neutral and more action-oriented than either of the first two. In this mode, the emphasis is upon studying how technology may be directed, or how alternative possibilities may be selected, so as to maximize identified beneficial effects and minimize specified deleterious side-effects. Such an evaluation must include a study of possible alterations in market and political incentives and institutions so as to channel technology into beneficial directions in a more or less self-regulating manner.

Assessment activities might finally be distinguished relative to the *institutional settings* in which they occur: in the *private firm;* in a *mission-oriented agency* such as the Department of Defense or Transportation or the National Science Foundation (with respect to weather modification); in an *environmental-regulation agency* such as the Federal Water Pollution Control Administration or the Atomic Energy Commission (with respect to radio-isotope usage, radioactive-waste disposal, or power-reactor siting); in *consumer-protection* agencies such as the Food and Drug Administration or the Federal Trade Commission; in *resource-allocation agencies* such as the Federal Communications Commission, the Federal Power Commission, or the Federal Aviation Agency (with respect to SST); in *professional societies* such as the American Society for Testing and Materials; in *quasi-*

independent groups such as the National Research Council; by *congressional committee staffs;* by *Congress-wide bodies* such as the Legislative Reference Service or the General Accounting Office; in *executive planning or coordinating entities* such as the Office of Science and Technology, the President's Science Advisory Committee, the Federal Council on Science and Technology, or the Environmental Quality Council; or in *ad hoc* bodies such as the Telecommunications Task Force.

POSSIBLE PATTERNS OF RESPONSE TO ASSESSMENT

There are, of course, many ways to classify the uses of assessment and the kinds of actions that can be taken in response to it. It is possible, for example, to classify responses according to the *point of intervention* in the technological time scale from initial innovation to widespread diffusion. Or responses directed at *technologies* might be distinguished from responses directed at *supporting systems*.

A basic set of distinctions may be made in terms of the *change* that is ultimately sought—namely, *total abstention* (no change at all); or *selection of a different or modified technology;* or *modification of the introduction of a given technology* (by altering the supporting system in some way); or *alteration of some facet of the environment*, natural or social, with which the technology may eventually be expected to interact (either through further technology, or through law, or through education).

In a sense, these are the possible *ends* of assessment; but attention must be directed to *means* as well. In classifying the means by which assessments might be made to serve various ends, two basic questions can be identified:

First: Who is to take the initial post-assessment action: Congress? the Executive? an agency? a court? the mass media? a professional association? technological innovators themselves? Assessments, of course, may serve as bases for formal legislative or executive actions of various kinds, but their influence may also be felt in more subtle ways, as through public pressure upon, and criticism of, industrial or individual practices (for example, trash burning). It is easy to forget the extent to which even the most profit-minded entrepreneurial activity is influenced by social attitudes conveyed through the media or by the climate of opinion among people with whom businessmen come in contact. Even if no formal action is taken by any public agency as a result of a given technological assessment, therefore, it should not be assumed that the assessment will have no influence on decision-making processes. Indeed, assessment may be structured specifically to provide a framework for indirectly influencing decision-making by disseminating widely certain kinds of information or evaluation for use either by private groups or as an authoritative data base for future legal action. To some extent, the information responsibilities assigned to the Atomic Energy Commission and to the National Aeronautics and Space Administration to encourage industry to adopt innovations generated by federal research and development in these agencies are of this character, as are the extension activities of the Department of Agriculture and the Soil Conservation Service.

Second: In the event that some kind of governmental action is to be taken in response to assessment, it becomes important to ask what *form* such action is to take. Too little is known about the ways in which laws and administrative policies channel the directions of technological change to attempt an exhaustive classification of all possible answers, but several major alternatives have been identified by the panel:

1. Assessment may provide a basis for *resource-allocation decisions* in the public sector, including but not limited to

allocations for research and development. Thus, in response to a given assessment, the federal government may abandon or alter its support for a major technological project that it might otherwise have promoted; or it may increase its investment (either directly or by sharing risks, as in the Price-Anderson Act (7)) in a technology (either developing or already available) to alleviate unwanted secondary effects or to achieve desired primary objectives; or it may augment its support for basic research and development as a prelude to deeper assessment in some area; or it may invest in the establishment of a monitoring system designed to detect and evaluate the low-level effects of technologies, whether governmentally supported or otherwise, in the early stages of their introduction; or it may partially subsidize private efforts to undertake the needed research or monitoring in a given area; or it may alter the form of an existing subsidy; or it may expend funds to compensate, relocate, or rehabilitate groups injured by technological change.

2. Governmental response to assessment may take the form of legislative or administrative action *modifying private initiatives by internalizing costs or enforcing specific requirements*—as in the case of automotive safety standards, food and drug laws, or other consumer legislation. A critical issue, to which the panel has already referred, involves the choice between administering direct rules of conduct and readjusting the legal environment differently. Thus, it might be made advantageous for the affected parties to alter their behavior of their own accord—for example, by facilitating collective litigation to bring costs home to the persons responsible for creating diffuse injuries, or by enacting legislation to create either negative or positive financial incentives, such as economic penalties assessed against polluting

activities, or tax credits or public subsidies conferred upon activities which reduce pollution.

When outrage over an insult to the environment becomes acute, it is tempting to castigate the offenders and to establish control over their future through some sort of regulatory commission. Such commissions may on occasion provide the best answer, but the history of regulation has not always been a happy one. On the one hand, even with the best of motives, the gradual accommodations between the regulatory agency and the interests it is supposed to regulate may leave little regulation intact. On the other hand, regulatory agencies may tend to invade industrial responsibilities for detailed decisions, and thus gradually erode the initiative and sense of responsibility of corporate management. Moreover, and quite apart from these twin difficulties, technical regulatory activities rarely attract the most able and imaginative personnel, with the result that technical obsolescence is often the fate of rules and regulations, which are difficult enough even with the best of personnel to accommodate to a rapidly changing technological context.

3. It is important to note the possibility of *altering incentives other than by imposing penalties or awarding subsidies*. It is theoretically possible, for example, to create legal property rights in a shared resource like air or water, though this is sometimes bound to prove difficult. Another alternative is to internalize side-effects within the compass of wider units of decision-making. The sanitation authority of a community that discharges untreated sewage to a river, for example, may be merged with the water supply authority of a nearby community that uses the same river downstream as a source of supply; the new and larger authority thus created is

more likely to take into account the damaging effects of one of its functions on another.

The panel's efforts in this section to classify the many kinds of responses that technology assessments might trigger, and indeed all of the taxonomic materials contained in this appendix, should be viewed as our tentative contributions to what we hope will soon become a sustained and serious effort, in many centers of scholarship and inquiry, to impose a greater measure of order upon the issues encompassed by the exceedingly broad notion of "technology assessment," to the end that such issues might be better understood and, ultimately, more wisely resolved.

References and Notes to Appendix A

1. Recall the "tyranny of small decisions," referred to in Alfred E. Kahn, "The Tyranny of Small Decisions: Market Failures, Imperfections, and the Limits of Economics," *KYKLOS: International Review for Social Sciences, 19*, 23 ff. (Fasc. 1, 1966).
2. See Emmanuel G. Mesthene, "An Experiment in Understanding: The Harvard Program, Two Years After," *Technology and Culture, 7*, 475, 480 (Fall, 1966).
3. Emmanuel G. Mesthene, "The Rȯle of Technology in Society: Some General Implications of the Program's Research," in Harvard University Program on Technology and Society, *Fourth Annual Report, 1967–1968*, Cambridge, Mass., 46 (1968), describing a study by John R. Meyer and John F. Kain, *ibid*, 8–11.
4. One panel member, Edward C. Creutz, prepared a most instructive report in this connection, *Trace Element Contamination of the Environment—Can The Effects Be Anticipated?* (October 11, 1968). On file at the National Academy of Sciences.
5. See the discussion *supra*, pp. 44–45, 130. See also fn. 3, *supra*, and John F. Kain and Joseph J. Persky, "Alternatives to the Gilded Ghetto," *The Public Interest*, no. 14, 75 (Winter, 1969).
6. For a fuller discussion of the matters touched upon in this paragraph and the preceding one, see Emmanuel G. Mesthene, "How Technology Will Shape the Future," *Science, 161*, 135 ff. (July 12, 1968).
7. 71 Stat. 576 (1957).

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APPENDIX B

Statement by Morris Tanenbaum, General Manager, Engineering Division, Western Electric

A matter of critical significance, but insufficiently examined by the panel, concerns the potential effects of new technology-assessment mechanisms on the funding and direction of research and development in the private sector. This constitutes an important weakness in the report.

The final recommendation of the panel that new assessment mechanisms be concerned with publicly funded technology relieves this weakness somewhat. Nevertheless, it is a matter of long-range concern since the private sector has been traditionally the principal generator of technological innovation even when that innovation is publicly funded.

The support of research and innovation represents the highest risk investment that private enterprise undertakes. The introduction of a new product or the entry into a new area of commerce are perhaps the greatest risk decisions that a private enterprise makes. For this reason, these decisions are extraordinarily sensitive to the risk environment.

New technology-assessment mechanisms represent a major change in this environment and the effects of this change are very difficult to predict. Of course, the purpose of new assessment mechanisms is to produce changes which will guide technology in socially desirable directions. However, the assessment mechanisms themselves will have second-order consequences. To the extent that assessment can define the social requirements of new technology at an early stage, this could encourage private investment. However, to the degree that new assessment mechanisms create new uncertainties, this could discourage private investment in areas of technology which are at the focus of assessment activity. These may be the areas where innovation is most important and private participation most desirable.

The panel's report recognizes these factors (pgs. 87–89) and suggests that there are readily available mechanisms which can counter the changes in the risk environment. Specifically, increased price structures and subsidies are suggested to compensate for increased risk. However, it is not clear that increased prices would be desirable or acceptable in many important areas, especially those most closely associated with socially pressing needs. Subsidies imply the removal of the technological area from the private domain with the concomitant loss of private innovative incentives. The reasonable conclusion is that *there are no ready-made cures for the changes in the risk environment suggested above*. Indeed, any existing cures may have undesired second-order consequences of their own. These consequences must be examined specifically, and the panel has been unable to do this.

These considerations do not negate the panel's general conclusions concerning the growing need for consideration of the total effects of technological innovation and the panel's recommendations for the study and considered implementation of new assessment mechanisms. They do, however, emphasize that new assessment mechanisms will interact with a highly sensitive and critical part of our present technology- and innovation-generating structures. Thus any new assessment efforts must be most carefully considered from the viewpoint of these interactions to assure that technology assessment will perform the socially desirable duties for which it is created without irreparably damaging the systems of innovation that it is designed to stimulate and guide.

APPENDIX C

Notes on Contributors

HENDRIK W. BODE was born in Madison, Wisconsin, in 1905. A graduate of Ohio State University in 1924, Dr. Bode remained at Ohio to earn his masters degree in 1926 and then received his Ph.D. from Columbia in 1935. His professional experiences include forty-one years with the Bell Telephone Laboratories as a member of the Technical Staff, serving three years as Director of Mathematical Research, three years as Director of Research in the Physical Sciences, and nearly a decade as Vice-President of Bell. In 1967 Dr. Bode left the Bell Laboratories to become Gordon McKay Professor of Systems Engineering at Harvard University. He is a member of the National Academy of Sciences, a founding member of the National Academy of Engineering, a member of the American Academy of Arts and Sciences, and a member of the American Association for the Advancement of Science. Awarded the Presidential Certificate of Merit in 1948 and the Edison Medal of the Institute of Electrical and Electronic Engineers in 1969, Dr. Bode holds over two dozen patents, is the author of numerous papers on electric circuit theory and related subjects, and has written the book *Network Analysis and Feedback Amplifier Design* (1945).

RAYMOND BOWERS is Professor of Physics and member of the Laboratory of Atomic and Solid State Physics at Cornell University. Dr. Bowers is also Deputy Director of the Cornell University Interdisciplinary Program on

Science, Technology and Society. Born in London, England, in 1927, he attended the University of London and Oxford University, receiving a bachelors degree in 1948 and a doctor of philosophy degree in 1951. From 1951 to 1954 he was a research fellow at the University of Chicago, and from 1954 to 1960 he was a research physicist for the Westinghouse Electric Corporation. From July 1966 to September 1967, Dr. Bowers served as a member of the staff of the Office of Science and Technology, Executive Office of the President, where he was concerned with questions of national science policy. He has continued to work in the area of science policy through service on national committees and also in the Cornell program. Dr. Bowers has been a consultant to Westinghouse, IBM, RCA, and United Aircraft Corporation. His research interests have spanned many aspects of solid-state physics and the physics of very low temperatures. He is currently studying the phenomenon of plasma waves in solids.

HARVEY BROOKS, Dean of Engineering and Applied Physics and a member of the Faculty of Public Administration at Harvard University, was born in Cleveland, Ohio, in 1915. He earned his A.B. from Yale in 1937, spent a year in graduate study at Cambridge University, and received his Ph.D. in physics from Harvard in 1940. He was a member of the Society of Fellows at Harvard. Dr. Brooks holds honorary degrees from Harvard, Yale, Brown, Kenyon, and Union. Currently the Chairman of the Committee on Science and Public Policy of the National Academy of Sciences, he is also a member of the National Science Board, a member of the National Academies of Science and Engineering, a consultant-at-large to the President's Science Advisory Committee, a consultant to the Scientific Directorate of the Organization for Economic Cooperation and Development, and was for many years a member of the Advisory Committee on Reactor Safeguards of the Atomic Energy Commission. He is a member of the Naval Research Advisory Committee. In addition, he is editor-in-chief of the journal *Physics and Chemistry of Solids* and author of a wide variety of papers and essays. In 1960, Dr. Brooks received the Ernest Orlando Lawrence Award of the Atomic Energy Commission.

EDWARD C. CREUTZ, a native of Beaver Dam, Wisconsin, born in 1913, is Vice President-Research and Development of Gulf General Atomic, Inc., and Director of the company's John Jay Hopkins Laboratory for Pure and Applied Science in San Diego, California. He received his B.A. degree in 1936 and his Ph.D. degree in 1939 from the University of Wisconsin. From 1942 to 1944 he headed the first group to undertake metallurgical studies of uranium, beryllium, and aluminum for the Manhattan Project. This work led to the successful development of the fuel elements for the first nuclear reactors at Oak Ridge and Hanford. Between 1944 and 1946 he was group leader at the Los Alamos Scientific Laboratory when the primary work on the atomic bomb was done. Before joining Gulf General Atomic, Dr. Creutz was Head of the Department of Physics and Director of the Nuclear Research Center at Carnegie Institute of Technology. During 1955–56, he held a special assignment as scientist-at-large evaluating the United States' controlled thermonuclear program for the Atomic Energy Commission. Dr. Creutz's broad interest in science includes the publication of articles in physics, as well as metallurgical and botanical subjects. He has been a member of the Divisional Committee for Science Education of the National Science Foundation, and

Director-at-large of the Governing Board of the American Institute of Physics.

A. HUNTER DUPREE, the George L. Littlefield Professor of American History at Brown University, was born in Hillsboro, Texas, in 1921. A graduate of Oberlin College, he earned his Ph.D. from Harvard in 1952. His professional posts have included eleven years as Professor of History at the University of California at Berkeley; two years as Assistant to the Chancellor; and varying periods of service as referee for research proposals to the Social Science Division of the National Science Foundation, as a member of the Foundation's Panel on History, as an adviser to the American Institute of Physics, as a member of the council of the History of Science Society, and as a member of the board of editors of that Society's journal, *Isis*. In addition to numerous government consultantships, he has been called upon by the University of California to serve on advisory committees for educational television, natural resources, public education in science and technology, and a humanities institute. His extensive publications include three books, *Science in the Federal Government: A History of Policies and Activities* (1957), *Asa Gray—1810–1888* (1959), and *Science and the Emergence of Modern America* (1953).

RALPH W. GERARD, a native of Harvey, Illinois, was born in 1900. Currently Dean of the Graduate Division, Professor of Biology, and Director of Special Studies at the University of California at Irvine, Dr. Gerard is internationally known for his pioneer work on the chemical and electrical activity of nerve and of brain. He has lectured on six continents, has served as professor at eight universities, and has received a number of honorary degrees and foreign medals and awards. He is a member of numerous learned societies, among them the National Academy of Sciences, and has been President of the American Physiological Society. Dr. Gerard is or has been consultant to various governmental and other institutions in this country and abroad and has written and lectured extensively in the behavioral and systems science areas and their application to human affairs. His nine books include *Unresting Cells* (1940), *The Body Functions* (1941), *Food for Life* (1952), *Mirror to Physiology: A Self-Survey of Physiological Science* (1958), and *Computers and Education* (1967).

NORMAN KAPLAN, born in 1923 in New York City, has been Professor of Sociology at The George Washington University and Senior Staff Scientist in the Program of Policy Studies in Science and Technology. In the fall of 1969 he is assuming the post of Professor of Sociology and Chairman of the Department of Sociology and Anthropology at Northeastern University in Boston. He has also been on the faculties of the University of Pennsylvania, Cornell, and Columbia. He received his Ph.D. in Sociology from Columbia University in 1955. He edited and contributed to *Science and Society* (1965). He has also been a contributing author of *The Handbook of Modern Sociology* (1964), *The Management of Scientists* (1964), and the *International Encyclopedia of the Social Sciences* (1968), and has published papers on science and society in various scholarly journals.

MILTON KATZ, the Henry L. Stimson Professor of Law and Director of International Legal Studies, Harvard Law School, was born in New York City in 1907. He is a member of the Harvard University Administrative Committee for International Studies and the Faculty Committees for the Development Advisory Service, the Center for Middle Eastern Studies, and the Committee on Regional studies. He is also a Research Associate, Program in Technology and Society, Harvard University. He received his A.B. from Harvard College in 1927. A year later, he entered Harvard Law School, receiving his LL.B. in 1931. He served as Law Clerk to U.S. Circuit Judge Julian W. Mack in 1931–32. From 1935 to 1938, he was Executive Assistant to the Chairman and Special Counsel of the Securities and Exchange Commission. The following year he was Special Assistant to the U.S. Attorney General. From 1941 to 1943, Professor Katz was Solicitor of the War Production Board, and during part of that time he was also U.S. Executive Officer of the Combined Production and Resources Board (U.S.A.-United Kingdom-Canada). In 1943, he was appointed to the Office of Strategic Services in Washington. Following World War II, he was appointed Byrne Professor of Administrative Law at Harvard University. In 1950–51, he was the U.S. Special Representative in Europe, with the rank of Ambassador Extraordinary and Plenipotentiary. As such, he was chief of the Marshall Plan in Europe. In 1950–51, concurrently with his Marshall Plan duties, he served as the Chairman and U.S. Member of the Financial and Economic Committee under NATO, and as U.S. Representative to the United Nations Economic Commission for Europe. From September 1951 to June 1954, Professor Katz was Associate Director of the Ford Foundation. In 1954, he returned to Harvard to his present post. He was Chairman, Committee on Manpower, White House Conference on International Cooperation in 1965, and he is currently Chairman of the Committee on Life Sciences and Social Policy of the National Academy of Sciences-National Research Council and a Fellow of the American Academy of Arts and Sciences. Books by Professor Katz include *The Relevance of International Adjudication* (1968), *The Things That Are Caesar's* (1966), *The Law of International*

Transactions and Relations: Cases and Materials (with Kingman Brewster, Jr.) (1960), *Government Under Law and the Individual* (editor and co-author) (1957), and *Cases and Materials in Administrative Law* (1947). He has also published a variety of articles on law, foreign policy, education, and foundations.

MELVIN KRANZBERG was born in St. Louis, Missouri, in 1917. He received his A.B. from Amherst College and then studied at Harvard University, where he earned his Ph.D. in 1942. Dr. Kranzberg has served as a Vice-President of the American Association for the Advancement of Science and Chairman of its Section L (History and Philosophy of Science). He is a former Chairman of the Humanistic-Social Division of the American Society for Engineering Education and is currently Chairman of the Historical Advisory Committee of the National Aeronautics and Space Administration and Vice-Chairman of the United States National Committee of the International Union of the History and Philosophy of Science. He is the founder of the Society for the History of Technology and editor of its quarterly journal, *Technology and Culture*. Dr. Kranzberg is editor of the two-volume *Technology of Western Civilization* (1967) and the author of several books and numerous articles in encyclopedias and scholarly journals on engineering education, French history, and the history of science and technology. Awarded the Leonardo da Vinci Medal of the Society for the History of Technology in 1967, he is now Professor of History and Director of the Graduate Program in the History of Science and Technology at Case-Western Reserve University.

HANS H. LANDSBERG was born in Germany in 1913. He studied at the London School of Economics and Columbia University. His professional experience includes a broad association with the United Nations as a member of the Relief and Rehabilitation Administration in Italy in 1946 and the Food and Agriculture Organization from 1947 to 1949. He spent the years 1950 to 1955 as an economist in the Office of the Economic Advisor to the Israel Government. A member of the American Economic Association; the Federal Power Commission's Power Requirements Special Technical Committee; and the Executive Committee, Study of the Consequences of Population Change and Their Implications for National and International Policies of the National Academy of Sciences, Mr. Landsberg sits on the Advisory Board of *Technological Forecasting*. He has authored and co-authored a number of articles and books, including *Natural Resources for U.S. Growth* (1964). Since 1960 he has been Director of the Resource Appraisal Program of Resources for the Future, Inc.

GENE M. LYONS, born in 1924 in Revere, Massachusetts, is Professor of Government and Chairman of the Department of Government at Dartmouth College. Professor Lyons was graduated from Tufts College in 1947, received a License en Science Politique at the Graduate Institute of International Studies in Geneva, Switzerland, in 1949, and took his doctoral degree at Columbia in 1958. From 1966 to 1968, he served as Executive Secretary of the Advisory Committee on Government Programs in the Behavioral Sciences, National Academy of Sciences-National Research Council. Professor Lyons was the co-author (with the late John Masland) of *Education and Military Leadership* (1959). His book, *Military Policy and Economic Aid*, was published in 1961, and a book written with Professor Louis Morton, *Schools for Strategy*, was published in 1965. His latest book, *The Uneasy Partnership: Social Science and the Federal Government in the Twentieth Century*, will be published in September 1969. Professor

Lyons is also editor and contributor to two studies published under the auspices of the Dartmouth Public Affairs Center in 1965: "America: Purpose and Power," and "European Views of America." He has contributed frequently to professional journals and other publications.

LOUIS H. MAYO, currently Vice-President for Advanced Policy Studies and Director of the Program of Policy Studies in Science and Technology at The George Washington University, was born in Prestonsburg, Kentucky, in 1918. A graduate of the United States Naval Academy, the University of Virginia Law School, and the Yale University Law School, where he received his S.J.D. in 1953, Dean Mayo's professional experience includes service as a member of the Law School Faculty and Dean of the Graduate School of Public Law at George Washington, as Executive Secretary of the Network Study Staff of the Federal Communications Commission, and as a member of the White House Task Force on Disarmament in 1956. He has also been a member of Project ARISTOTLE, the Task Group on Standards of Measurement and Evaluation. Dean Mayo's publications span a wide variety of scholarly and legal journals, and he recently published a series of studies of the technology-assessment function in connection with his work in the Program of Policy Studies in Science and Technology.

GERARD PIEL, a native of Long Island, New York, was born in 1915. After serving as science editor for *Life Magazine* from 1939 to 1945, he helped organize the *Scientific American* and is currently president and publisher of that journal. A graduate of Phillips Academy and Harvard College (A.B. *magna cum laude*, 1937), Mr. Piel holds honorary degrees from a number of major universities, including Brandeis, Carnegie-

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HERBERT A. SIMON, born in 1916 in Milwaukee, Wisconsin, is Richard King Mellon Professor of Computer Science and Psychology at the Carnegie Institute of Technology, Chairman of the Division of Behavioral Sciences of the National Research Council, and a member of the President's Science Advisory Committee. A graduate of the University of Chicago, where he received his Ph.D. in 1943, Dr. Simon holds honorary degrees from Yale University, Case Institute of Technology, Lund University, and the University of Chicago. He is a fellow of a number of learned societies including the American Psychological and American Sociological Associations. A member of the National Academy of Sciences, the National Academy of Public Administration, and the Société Royale des Lettres de Lund, Dr. Simon has served on the faculties of the University of Chicago, the Illinois Institute of Technology, and the Carnegie Institute of Technology. He has also been consultant to the RAND Corporation and the Cowles Foundation for Research Economics and is a former chairman of the Board of Directors of the Social Science Research Council. He is the author of a number of articles and books, including *Models of Man* (1956), *Organizations* (1958), *The New Science of Management Decision* (1960), and *The Shape of Automation* (1965).

CYRIL STANLEY SMITH, an American citizen since 1940, was born in Birmingham, England, in 1903. He graduated from Birmingham in 1924 and received a

Doctor of Science degree from the Massachusetts Institute of Technology in 1926. During World War II, he served as Associate Division Leader in Charge of Metallurgy at the Los Alamos Scientific Laboratory. He then moved to the University of Chicago to become Director of the Institute for the Study of Metals and Professor of Metallurgy. Winner of the U.S. Presidential Medal for Merit in 1946 and the Leonardo da Vinci Medal of the Society for the History of Technology in 1966; a member of the National Academy of Sciences, of the General Advisory Committee, Atomic Energy Commission, from 1946 to 1952, and of the President's Science Advisory Committee in 1959; and past President of the Society for the History of Technology, Dr. Smith is presently Institute Professor, Professor of History of Technology and Science, and Professor of Metallurgy at M.I.T., a position he assumed in 1961.

MORRIS TANENBAUM was born in Huntington, West Virginia, in 1928. A graduate of Johns Hopkins University, with a Ph.D. in physical chemistry from Princeton in 1952, Dr. Tanenbaum began his career as a member of the Technical Staff of the Bell Telephone Laboratories. At Bell he became Assistant Director of the Metallurgical Research Laboratories in 1960 and Director of the Solid State Device Laboratory in 1962. He joined Western Electric in 1964 as Director of Research and Development at the company's Engineering Research Center in Princeton, New Jersey, and assumed his present position as General Manager of the Engineering Division in 1968. Dr. Tanenbaum developed the first successful silicon diffused base transistors and pnpn diodes and has secured several patents on the fabrication of semiconductive devices and the preparation of semiconductor and magnetic materials. A Director of the

American Society for Testing and Materials and a member of the Materials Advisory Board of the National Academy of Sciences, he has served in numerous advisory groups for government, university, and professional organizations and currently sits on the editorial advisory boards of several leading technical journals, including *Solid State Electronics* and the *Journal of Materials Science and Engineering*.

LAURENCE H. TRIBE was born in Shanghai, China, in 1941, and has lived in the United States since 1946. Currently Assistant Professor of Law at Harvard University and a Research Associate to the Harvard University Program on Technology and Society, he was elected to Phi Beta Kappa in his junior year at Harvard College and, in 1962, earned his A.B. degree *magna cum laude* with highest honors, having been awarded a *summa cum laude* by the Harvard Department of Mathematics. After spending a year at the Harvard Graduate School of Arts and Sciences as a National Science Foundation Fellow and an Honorary Woodrow Wilson Fellow, he attended the Harvard Law School, where, in 1966, he received his L.L.B. degree *magna cum laude* and was the recipient of the Beale Prize. Professor Tribe was Law Clerk to Justice Mathew O. Tobriner of the California Supreme Court from 1966 to 1967 and came to his position as Executive Director of the Technology Assessment Panel from the Supreme Court of the United States, where he spent the 1967 Term as Law Clerk to Mr. Justice Stewart. Professor Tribe is the author of a Lawrence Radiation Laboratory report, "Numerical Solution of Ill-Conditioned Linear Systems" (1959), and a published set of lectures, *Criminal Law Enforcement and the Constitution* (1967).

DAEL WOLFLE, born in 1906 in Puyallup, Washington, is executive officer of the American Association for the Advancement of Science and publisher of the magazine *Science*. He graduated from the University of Washington in 1927, received his Ph.D. from Ohio State University in 1931, and has been the recipient of several honorary degrees. Dr. Wolfle has served as consultant to the Organisation for Economic Cooperation and Development and a number of other agencies. He received the Presidential Certificate of Merit in 1948 and is the author of *America's Resources of Specialized Talent* (1954), *Science and Public Policy* (1959), and numerous editorials on science policy matters in *Science*.