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TECHNOLOGY AS SOCIAL ORGANIZATION

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STUDIES IN PUBLIC ORGANIZATION

Through this series of working papers, the Institute of Governmental Studies, Berkeley, provides a channel through which scholars at work on problems of public organization may present their thoughts in a convenient form and without too much delay. We envision this series as a modest undertaking, but we hope that "Studies in Public Organization" will make some contribution toward an understanding of the properties that describe the variety of public organizational systems that exist throughout the world. We want also to note that no single formula will dominate; the series will contain papers that are theoretical, methodological, comparative, or historical. It is open to faculty and student contributions alike, not restricted to this campus, and its objective is to publish papers that engage important problems and present interesting ideas.

TECHNOLOGY-AS-SOCIAL-ORGANIZATION:

Implications for Policy Analysis

Introduction

Over the past decade, efforts in the U.S. to anticipate the effects of technological development upon the physical and biological environment and upon economic and social change have grown steadily. The political legitimacy of this work is evident in the institutionalization of environmental impact analysis and technology assessment in the federal government. During the same period, the more general field of policy analysis has also flourished. These areas share an intention to inform decision-makers and attentive publics concerning the consequences of present policy choices; and an uneasiness with merely trial-and-error learning regarding programs where the negative consequences of future impacts could be great. In each field, "technology" is seen as a significant source of change. Proponents of programs with important technical elements argue for changes necessary to implement their preferences. Opponents emphasize the potentially costly and harmful effects of carrying out proposals. Both proponents and opponents look to studies predicting future effects to buttress their positions.

A good deal of attention has been paid to estimating the potential economic benefits of new or improved technologies and the incentives necessary to encourage their deployment. By and large, such studies implicitly assume that the overall economic and military benefits of improved technologies are so substantial that the negative surprises or effects they might occasion need draw little serious notice. On the other hand, a growing number of studies emphasize the possible disruptive or problematical effects of technical development but ignore questions of improving the chances of industrial commercialization. In the cases, for example, of nuclear power (and radioactive waste management), genetic engineering, computerization of

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business information, off shore oil development, or the development of new drugs, strong economic incentives to plunge ahead already seem evident. Yet, many people sense in these areas the potential for grave social or personal harm sufficient to counter estimates of economic gains. When this is the case, trial and error/common sense learning alone does not inspire much confidence as a basis for improving policy and complex decision-making; rather attempts to anticipate and avoid untoward health, social and environmental misfortune and nasty surprises take on heightened urgency.

Accurately anticipating future effects of technological—or policy—implementation requires a keen conceptual understanding of the relationships of technology to social experience—in effect, a *predictive theory* of technology and social and environmental change. Its core should be coherent descriptions of the technical phenomenon from which straightforward connections can be made between the proposed technology and the likely changes that the public, governmental agencies, and industrial organizations would experience were it to be widely deployed. Moreover, since there are few relationships in the social sciences that are assumed to be valid or law-like, it is necessary for analysts to make explicit the causal relationships they understand link the sources of changes to the specific changes themselves. And it is crucial that they do so in ways that permit empirical expression.

These injunctions are common ones in social science, but they are rarely followed in policy studies or technology assessments involving military or industrial technologies. It may be, in part, that those who do such analyses understand "technology" mainly in engineering or industrial terms, thus limiting the ways they think about "it" merely to engineering economic categories. But if these analysts did seek more refined, descriptive terms, they would find very few attempts to develop a conceptual language that self-consciously links technological sources of organizational and social change to those changes themselves. This paper takes up that task by developing an expanded view of *Technology-as-Social-Organization* to complement the engineering view of technologies as machines and structures.

It is obvious that the capacity for precise predictive analysis regarding social and organizational change is not yet available. Forecasts of changes stemming from technical developments or public policy programs are gross at best and, upon review, often seem more flawed than accurate. Yet the technical programs promoted by industry and government do result in major surprises, and the demand for anticipatory analysis continues.

At our present stage of limited understanding, how should we view such efforts? First, policy analysis , and technology assessment and policy analysis especially, is best viewed as an aid in avoiding programs that would make things worse—essentially *exercises in damage limitation.* To suppose that we are able systematically to secure the social good through technical or policy fixes is unwarranted. Rather, a more credible objective for technology assessment and policy analysis is the *avoidance of excessive social strain.* This is the touchstone of our perspective.

Second, the urgency of "policy analysis" or "assessment" efforts should be in proportion to the degree that the economic sectors associated with a technology do *not* approximate the classic market system. When the industrial sectors involved in deploying a technology have many producers *and* many buyers, the self-regulation of the system is more or less assured. Competition among many producers for many buyers results in the most efficient provision of technically stimulated benefits. And, as importantly, negative results are noted and their sources limited. (The exception is for effects that stem from long term cumulations of small changes that remain below the threshold of public notice until they have grown to substantial proportions, as in the case of air pollution from automobile emissions. This type of situation results in sudden appearance of public distress and political surprise. We will examine it as a special case of "high-risk" technology.)

When, however, competitive market conditions do *not* exist for both producers and buyers, self-correcting social mechanisms are flawed, and damaging consequences from lost economic efficiency and/or from social and environmental disruption may occur.[1] While keen foresight is limited by knowledge and imagination, it can, to some degree, compensate for eroded self-correcting structures.

Third, when technological elements of policy proposals provoke legislative or public debate, it is based on speculation about likely social changes, or about the desirability of developing a new technology in one way or another. Credible forecasts are not available. And in the absence of clear, full descriptions of technologies in their industrial and social forms, they are not likely to be. Thus, without *explicit* analyses of effects, proponents and opponents hold *implicitly* different views of what the technology may actually require, and hence, which institutions may benefit or suffer, and what consequences may flow from wide spread deployment. Cost/benefit or risk/benefit analyses, invariably based on economic reasoning assuming a near market situation, are offered by proponents to show that the new development would deliver more benefits than harm to society. Opponents attempt similar analsyes revealing that negative effects would overwhelm the benefits.

But few impact analyses or technological assessments satisfy technologists, governmental or industrial leaders, or organized intervenor groups. One reason is that most discussions offer mainly technical engineering results or highly aggregated economic estimates, usually promising positive outcomes. This does not provide a clear basis for decision-makers or groups in the public to judge whether or not changes in their social or economic circumstances will be significant. Rather, these incomplete descriptions become persuasive documents intended by the proponents to assuage the fears of the timid and obtain political acquiescence for technical deployment; for opponents they serve as instruments to evoke fears of serious, perhaps grievous, consequences and unjust concentration of benefits.

The perspective of technology and socio-political change advanced here is rooted in a sociological, rather than an engineering, understanding of "technology" and calls out substantially different questions requiring different data than has usually been available. Its central tenets are that:

-Technological developments can be viewed as a system of social and organizational relationships which, in a social sense, define the technology. In addition to being an intricate web of ideas, processes, and methods based on scientific work, "technology" is intrinsically a human process. People, working together, are absolutely necessary for the possibilities of new or improved technologies becoming available in a society. Without numbers of people cooperating closely in carrying out the activities necessary to realize the technical potential, its capacity will not be available to modify the physical environment, to enhance public health, to provide assistance for everyday labor, or for use in the countless ways we find to apply new technical capacities. Therefore, it is crucial to understand the interactions between the *organizations* that help to realize the potential of technology-as-concept, the *communities* which are directly in contact with the technology, and the overarching *societal institutions*—legal, political, economic, and social—within which both the communities and the technologies-as-organization operate.

- Only when a new technology promises to attain significant scale and industrial maturity does it become a matter of serious public policy concern. In a social or political sense, if a technology remains only scantily developed, it falls beneath the threshold of analytical interest. For our purpose, therefore, analysis must include a technology's properties both at early stages of development and as it becomes widely dispersed through large-scale organizations.

- The activities, people, , financial and other resources necessary to implement a technology, especially as it approaches large scale, are the primary stimulus for changes in social and economic effects felt by the people and community/ regional organizations or institutions that come "in contact" with "it."

- A technology's social and organizational properties will vary systematically as a function of its design and operational characteristics, the particular strategies employed to deploy it, and the scale it ultimately attains. As these properties vary, so does the character of social and political change.

- The communities, institutions and regions "in contact" with the technology have social properties that vary as a function of their demographic, economic, and political characteristics, and the particular national and state legal constraints within which these communities and institutions operate. (Discussed in a forthcoming paper.)

- The effective assessment of particular technologies requires a general understanding of the various effects different types of technologies have upon communities, institutions and regions, themselves possessing variable social characteristics.

And finally, two hypotheses that highlight special properties of advanced technologies:

- Advanced technologies, due to their intrinsic dependence upon very sophisticated conceptual and organizational requirements, will be highly resistant to modifications prompted by variations in local or national culture. Therefore, differences in local or regional effects of a particular advanced technology are more a function of the variations in local or regional conditions than of the design of the technology. (Discussed in a forthcoming paper.)

- In recent years, we have seen an increasing awareness of the growing physical, biological and social power and effectiveness of large scale, widely deployed technologies and their longer term consequences. This has led to a class of technologies perceived simultaneously to be both benefit rich and high risk, about which there is a growing demand for their very reliable, nearly failure-free operation. (Discussed in a forthcoming paper.)

This paper advances a conception of technology in terms closely related to the conceptual language of the social sciences. This allows us to link notions of technology more easily to familiar thinking about social and political dynamics in such a way that the effects on institutional developments occasioned by technologies possessing particular properties can be specified and subsequently verified. Without more complete descriptive language, technology assessments, and much of policy analysis, must remain the province of intuition subject to inordinate bias—as much the origin of controversy as its resolution.

Technology in an Expanded View

"Technology" means, in its usual restricted sense, a system of ideas and concepts rooted in scientific principles, which are the bases of machine prototypes, the buildings of the modern era, and productive work whereby the physical and biological world can be altered. This conception sees technology as the application of scientific principles to the solution of socially-defined problems.[2] It is the most generally shared view, held in common by engineers and technical administrators, architects and builders, as they attempt to transcend human limitations, through flight, rapid ground travel, healing and housing, as well as production of material goods. The results of such applications produce at least two distinct classes of *technologies as physical objects:* the *machines* which enhance and encumber our lives, and the physical *structures* within which we live and work and that house the productive and monitoring machines of our culture.[3] While the logic of technology derived from physical laws does not require this distinction, social impact and public policy analyses does require it.

The "sociologics" of machines and structures are quite likely to differ substantially in their respective social and political properties, dominant mode of financing, and the policy criteria applied to them.[4] Failure to distinguish between machines and structures—a common source of error in policy analysis and studies of technology and economic change—leads to lumping together television sets and roads, kidney dialysis machines and nuclear reactors, computers and shopping centers, and aircraft and airports, as if they had similar systemic properties. Clearly this is not the case, except perhaps in the grossest economic sense. One distinctive difference between machines and structures is in the process of manufacture, and construction and operation, and points to another crucial distinction: *technology-as-operational-process.* This aspect—generally overlooked—is one of the most important in understanding the longer term influences of technologies on our experience.

The step-by-step processes of technical integration and coordination, devised devised by industrial engineers and systems designers, build on the intrinsic "technologic" of manufacture, construction and operation. These processes lay out, often in intricate detail, the imperative relationships of machines to structures and machines to machines, as well as the standard operating procedures, that must be carried out if the technology is to fulfill its promise. The characteristics of different operating processes, e.g., the assembly line, the procedures for radar-controlled missile interception or aircraft landing, high-rise building construction, or the protocol for organ transplants, vary considerably and signal different cooperating imperatives and organizational relationships and, hence, different experiences for those directly involved.

Indeed, the operational imperatives intrinsic to the particular design of the technical system act as a kind of behavioral genetic code, stipulating the degree of constraint or flexibility possible for system operators, sometimes for those who take advantage of the technology, and occasionally, for communities and governments.[5] Thus, assessing a technology's social effects or demanding that "new technology should not change workers" calls for close attention to the relationship of operational processes to the activities of the people who cooperate in turning technical potential into available capacity.

Improved social impact and policy analysis requires a concept of technology that is as refined in sociological terms as the notions of technology as technical concept, prototypes and operational processes now embedded in current engineering perspectives. Such a concept should be rooted in a view of technology as an organized system of human beings cooperating in quite complex ways, maintaining, sometimes improving, powerful capacities which others may use to alter their lives. In addition to the question, "What is technology?" we must ask: "*Who is technology?*" "How does the design of technology shape relationships among persons?" "How are the social properties of particular technologies related to social and political dynamics of community and national life?"

Technology understood as a *form of social organization* offers a major step toward answering these questions. From this perspective, then, technology is seen as a system of cooperative relationships among people—designers, engineers, technical managers, support staff, technicians, security people, etc.—who act out the cognitive ideas, develop the prototypes and carry out the operational processes that make available to others what is promising in technical concept.[6] Also included are the organizations that produce and distribute technical products and services, as well as the firms that contribute both materials and trained personnel to these producing and distributing organizations. If technologies are thought of *only* in terms of engineering concepts, the manufactured forms they take, and the economic value they produce, then analyses of social effects are likely to be quite imprecise, often wrongheaded, and subject to inordinate error. This is especially true if the organizational requirements for wide spread delivery of technical capacity are not carefully delineated.

Figure 1 summarizes our perspective thus far. For purposes of understanding their social effects, technology should be conceived of as a human phenomenon which includes: 1) the technical professionals and their supporting units who are animated by scientifically grounded technical concepts and creative motivations, and fashion prototypes of machines and structures and devise operational processes, and 2) the social organizations of those who produce and distribute technical capacities to citizens and consumers. Variations in technical and professional doctrine and organizational practice prompt different ways of organizing to produce and distribute a technical capacity. Systematic analysis of their differences provides a basis for identifying the social properties of different types of technology. Without such work intuition will be the guide to specifying which activities should be modified, and in what ways, if technologies are to be designed to enhance desirable social and political conditions or, more realistically, to avoid

FIGURE 1

Technology in an Extended View*

Technology As:

Technology seen as:	POTENTIAL: Technical Conception	POTENTIAL: Technical Form	SOCIAL ACTIVITY: Social Behavior and Organization (techno-social system)	SOCIAL ACTIVITY: Effect and Consequence
Machine	Jumbo Jets	Prototype Aircraft →	Aircraft Assembly Line →	Delivered Capacity with 1st → 2nd → 3rd → Nth Order Consequences
Structure	Radial load stations	Scale model →	Airport Facilities →	
Operational Process	Radar and Control Coordination	Flight Demonstration →	Ground Controlled Approach Process →	
	POTENTIAL TECHNICAL CAPACITY		BASIS FOR TECHNOLOGICAL DELIVERY SYSTEMS	

* Examples taken from the air transportation field.

unexpected conflict and serious social strain. The next step, then, is to describe a technology's social organization in rather detailed terms so that direct connections to organizational and political changes might be made. In the next section, this task is begun at a general level, returning in the pages following to the problem of characterizing particular technologies.*

Technology as Social Stimulus

Analyses of the "social effects of technology"—based on this view—explicitly take the *deployment of a technology* as a significant stimulus for social change. "Technology" is seen as a cluster of newly introduced conditions—independent variables—whose variations are associated with different degrees of social change as the technology "spreads across" the society. Analytically, descriptions of technology-as-social organization must be linked quite directly to the experiences of the public, organized groups, elected political bodies, administrative and regulatory organizations, and finally back to the technologists themselves. Only by elaborating these relationships, in some detail for specific technological areas, can students of social change, policymakers, and citizens escape the vagueness of "what if" speculations which infects much current technology impact analysis. At present, we must depend mainly on impressionistic, intuitive feelings about "what would happen if" a large nuclear power plant were actually built along a seacoast; if solar energy devices really were widely installed; if engineering techniques to determine the sex of unborn babies were really widely employed; or if high-speed, computer-assisted electronic postal service becomes regularly available.

The simplified schema in Figure 2 serves as a framework for specifying different aspects of technology/society interactions. It indicates the general relationships of 1) the properties of technology-as-organization, and 2) the economic, human resources, and organizational requirements necessary for introducing and deploying it; to 3) the economic and social consequences of having assembled financial and human resources and altering political constraints in order to

* (A subsequent paper examines the source and consequences of organizational and social strain and the research and policy analytic implications of this view of technology and social impact.)

deploy it; 4) the governmental responses to such economic, political, and social changes; and 5) the effects which governmental responses might have on further technical development and/or control.[7]

Across the top of Figure 2 is the sequence of relationships associated with potential technical capacity discussed earlier. These include the innovative technical concepts, inventions, prototypes or models, the organizational processes, and the development phase in which the engineering feasibility of the new technical potential is determined. Considerable attention has been devoted to this phase in the literature on the stimulation of technical innovation and research administration.[8] But an understanding of the conditions that encourage technical innovations have only a limited bearing on the study of the *diffusion* of such technological capacity, or the assessment of "its" effects upon the society.

The first steps in the diffusion process obviously include decisions to back particular technical alternatives.[9] The manifest bases for such choices are usually engineering performance and costs. In the past, when policy-makers opted for a technology, they have tacitly assumed that there was sufficient knowledge of potential economic and social effects—who will benefit and who will be disadvantaged—to select an alternative without incurring grievous error. Benefits to promoters were so evident and the disadvantages to others seemed so dispersed that careful analyses of longer term effects rarely seemed warranted.

Indeed, many technologies do effect a "graceful entry" into society.[10] The benefits they promise in increased work efficiency, new communication possibilities or attractive consumer goods require few changes in the existing manufacturing or marketing systems. These technologies epitomize market driven technical progress where short term consumer and/or producer benefits are obvious. There are few visible "externalities," especially in early stages of deployment. In a sense, this type of technology has few, if any, jarring effects on the society. "Externalities" or negative social effects do not become significant, and technologies provide "continuous gratification" as their operators command larger "shares of the market" and approach mature large scale development. These properties are hoped for, indeed expected, by the promoters of all technical advances. When they are present, technologies do seem to be fountains of apparently automatic progress.

But all technologies that enter gracefully when they are "youthful" are not so amiable as they approach maturity. Awkwardness develops as they grow, and significant "externalities" become evident. It has become widely recognized that technological developments may prompt changes that studies limited to engineering and short term economic cost and benefit cannot foresee. The environmental impact analysis and technology assessment movements have resulted. In this climate, analytical questions concerning technology as a stimulus to social change—and a source of social strain—take on added importance.

Sources of Effects*

As a new technological capacity is developed from the earlier stages to demonstration and grows to full deployment and maturity, three sources of social change become apparent (indicated on Figure 2 by arrows I, II and III). The first is the changes in the economic and regulatory systems that are thought necessary for the new technology to "flourish". The second is the widespread availability of new opportunities for consumers or users. Third, there are less obvious changes in social institutions as they respond to the actions of the organizations whose economic and political power is increased due to successful production and distribution of the new capacity. These sources of change appear in sequential order; their effects are cumulative, and intensify as a function of the overall scale of the technical system. A thorough-going analysis of social impact (or a technology assessment) should include an examination of all

* The argument in this section assumes:

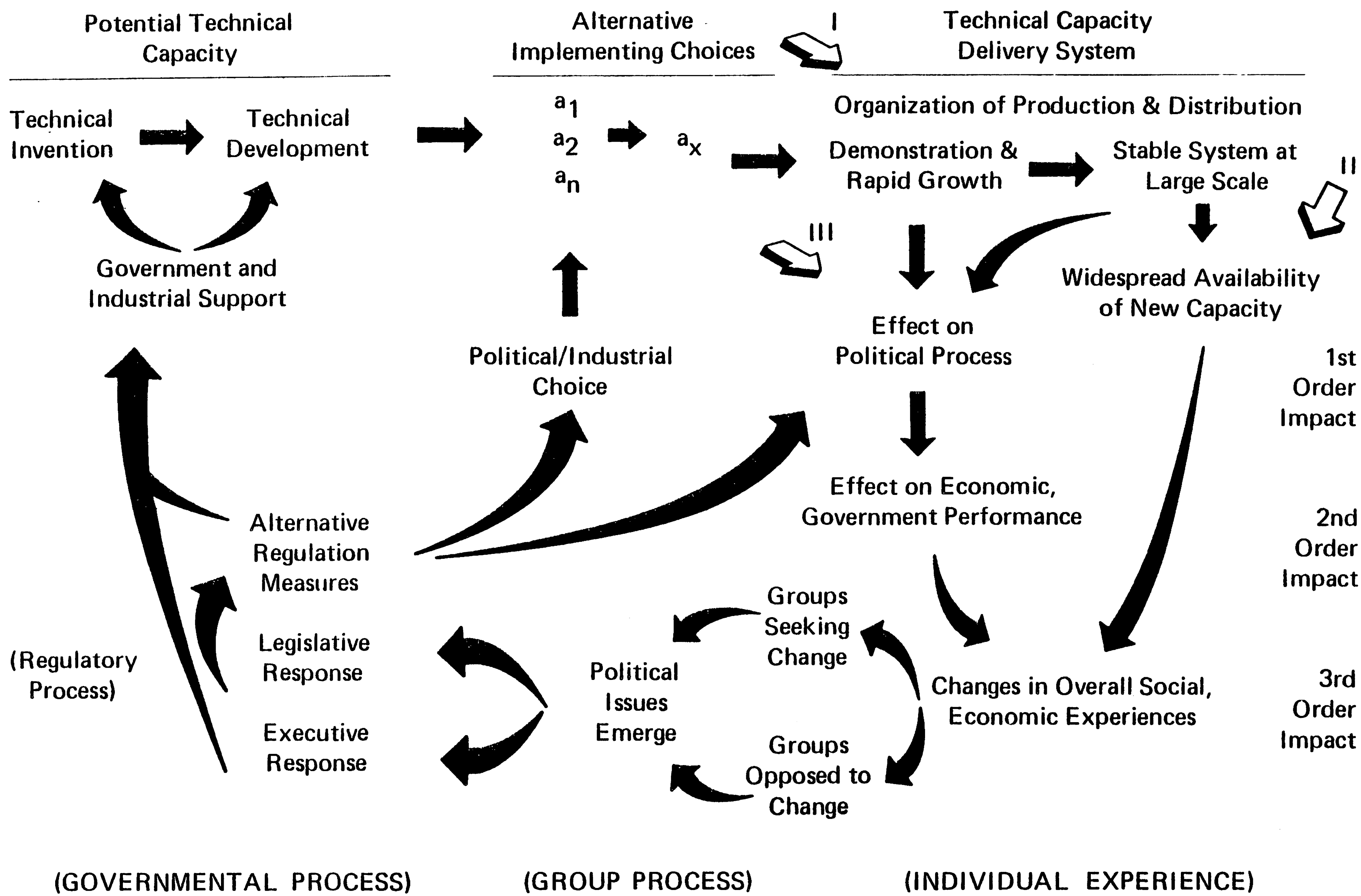
1) That social change is fundamentally a change in the distribution of economic and social privileges within a community or society. It is signaled by the relative increase or decrease in the capacity people have to accrue economic and social status.

2) That technology, as defined here, affords us tested or proposed capacities to alter the world, to change personal experience, and to organize productive activity. With expected or actual widespread distribution of the capacity, the particular distribution of privilege within a community or society may be reinforced or transformed: a new capacity often alters the relative advantage of groups or individuals in competition for economic and social status, and may either reinforce or threaten existing patterns of privilege.

3) That political change is a consequence of changes in and/or aspirations for changes in the distribution of economic and social privileges within a community or society. Issues are brought into the public sphere—become political—when groups experience sufficiently similar circumstances that they see in them a common interest around which to organize and press claims on governmental institutions for change or maintenance of the *status quo*.

FIGURE 2

Simplified Pattern of Technology-Society Interaction



three; the first two have each been the dominant focus for separate types of technology assessments. The third source has been the concern of many critiques of the industrial system. To date, few have integrated all three technology assessments or policy analyses.

Accommodations for Deployment[11] The first source of effect—changes in economic conditions, such as concentration of capital, deferred return, etc., and local, state, and national regulatory constraints such as building codes, labor laws, and environmental health and safety regulations—appear early in the deployment process.[12] Changes in economic conditions during the initial stages of technical development are likely only to affect matters on a local level and may be part of the "graceful entry" of a technology. As such, they draw little interest since they signal a technology that is responding to the market. But the studies that chronicle the politics of technological decisions point to non-economic facts that bear strongly on choosing one technical alternative or another. Is it simply economic costs and benefits that lead to the choice of automated transit system, rather than manually-controlled trains; dialysis equipment concentrated in large centralized facilities, rather than designed for home care; or airports capable of accepting jumbo jets rather than supersonic transports? In effect, for some technologies, political factors join with economic costs in prompting industry and/or government to pursue a particular technical alternative. Little attention has been paid to ferreting out the properties of technical systems that introduce non-economic factors, say maintaining political position, into decisions supporting the deployment of a particular technical option.[13]

Not all technologies are received gracefully within the market structure at the time of their initial development. Some fail early due to economic costs. Others seem to promise such long term advantages, even in the face of high initial cost, that there are pressures from industry and often government agencies to assure "safe entry" by intervening in the market on the "technologies' behalf". Tax incentive may be arranged, as in the recent attempt to encourage solar energy technologies. Assured markets may be guaranteed, as in the development of high technology weapons and in the legal requirement that electric utilities purchase power generated by private producers at a price equal to that the utilities would have had to pay for a like amount of electricity. At the local level, industrial promoters convince city elites that variances from local development codes will increase tax flows to provide public surcease, maintain employment or enhance a community's prestige. Sometimes there is massive governmental subsidy for the deployment of a technology to demonstrate its commercial benefits as in the case of nuclear power reactors.

In each case, purely market conditions have been altered during the initial stages of deployment with the expectation that economic or political benefits would mount enough as the technology approached maturity to warrant the initial subsidizing expense. Some "technology assessments" seek to identify change in the dynamics of economic and political institutions—corporations, government agencies, legislations and the courts—that would improve the deployment of the technology.[14] The objective is to pinpoint the political, economic, and sometime regulatory conditions that seem to thwart the diffusion of technical innovation. Measures are then proposed that are expected to ease the difficulties of deployers. When such changes are made, they represent a "forced entry", rather than "natural" workings of the economic market place. As such, these interventions in the market become, in part, the first social effects (though they are rarely included in technology assessments). They often trigger surprising second-order consequences in the structure of the law, relationships between economic institutions and governmental agencies, and in the dynamics of social organizations which, at small scale, seem neither obvious nor troublesome.[15]

As the technology spreads and the precedents for changes applied to increasing numbers of communities and industries, "forced entry" measures stimulate considerable tension as increased "political energy" is necessary to enforce changes, clarify new legal relationships, etc. Conflict results when established relationships between competitors are disturbed. An early example is the case, in the mid-1930's, of goverment contracts with certain struggling airlines for U.S. airmail routes. If the political energy needed to prevail is considerable, we can say that there is significant *deployment strain* within the country. And this should be included in the catalogue of social effects. Some of the most vivid examples of such conflicts are those bubbling around policies for the disposing of radioactive wastes—an area in which technology assessors do consider early conflict as a serious impact.[16]

Nuclear waste management—a clear example of a technology forcing entry—demonstrates other important pressures for change. These are the more subtle changes in legal precedent, positions in the market, or shifts in political advantage associated with forced measures. The process of "consultation and concurrence" that is emerging to assure the federal government, the states and local political jurisdictions significant roles in authenticating the selection of potential disposal sites for nuclear waste is likely to challenge traditional conceptions of federalist relationships. These procedures may spill over into other areas, such as the disposal of other hazardous materials and technologies. If many technical areas were involved, substantial change in the wider relationships between levels of government could result—a significant longer range impact of hazardous technology.

Availability of New Capacity. The second source of effect, more often emphasized in technology assessments, is schematically represented on the extreme right of Figure 2 (Arrow II). Every technology, as it reaches industrial maturity, has both intended and unintended capacities. There are, of course, new capacities to alter the physical and biological world which are expected, indeed sought, by designers and promoters. And technology also prompts attractive environmental and social effects that surprise both designers and the public. Although it is difficult to predict them precisely, we expect such positive results from new capacities as the full range of uses to which a new, widely-dispersed, technology can be put, is opened up. People frequently invent uses for a particular technology never envisioned by those who designed it.[17] Improved air transport, say through development of efficient short-haul STOL aircraft, provides a new option for moving people and freight about a region more frequently, reliably, and flexibly. It would very likely increase the flow of commercial goods throughout the U.S. And because executives could more easily travel to remote areas, it might contribute to the growth of local factories and, indirectly, the population of small towns. Other uses can be imagined: new educational opportunities, medical services, and recreational options as a result of reliable transport access to remote regions.

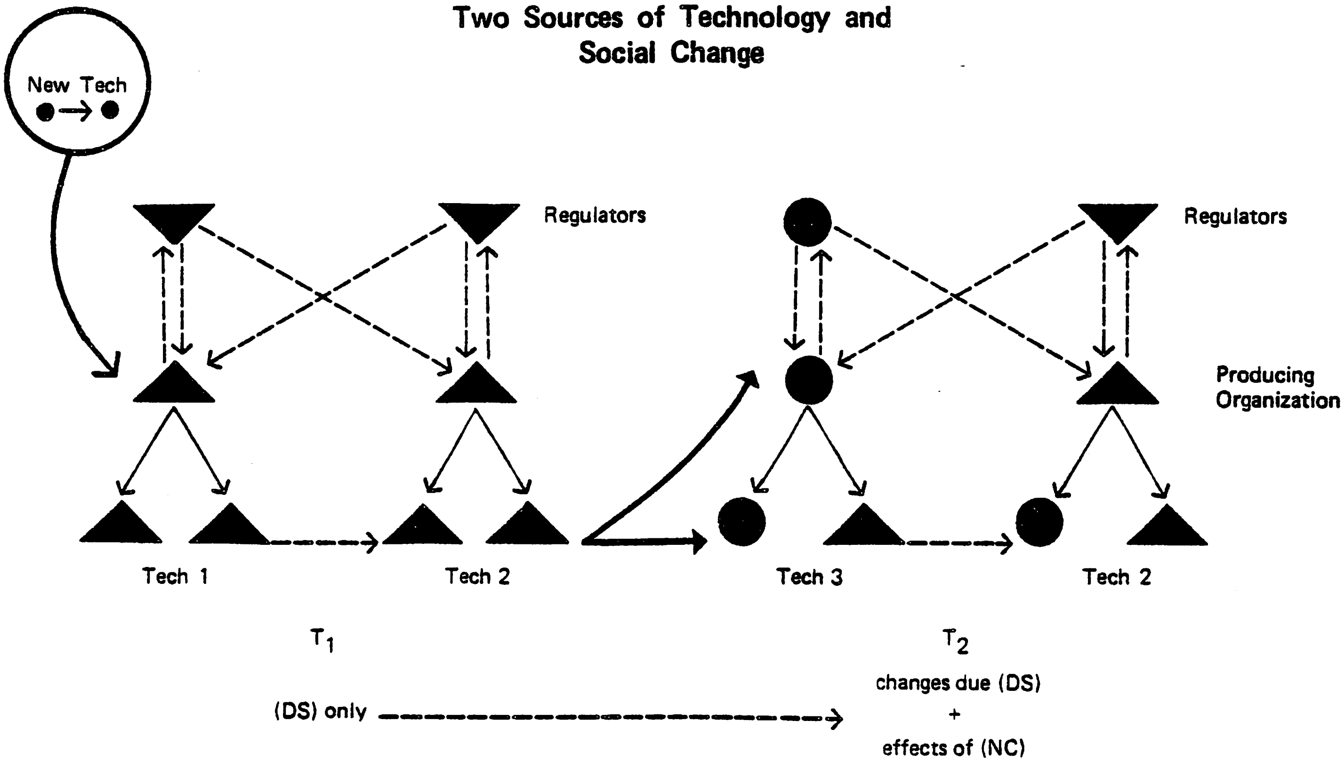
But there may be unintended capabilities, as well; the possibilities of changes that could be disruptive and painful and are not sought. STOL aircraft and STOL ports would heighten our dependence on liquid fuels, increase air pollution, disrupt the ecological balance of airport environs, and increase noise levels significantly. Were STOL systems widely available, they could increase the transport of people and materials to the point where the social balance of rural communities would be threatened. Thus, the expected beneficial capacities that stimulate the development of advanced technologies are often accompanied by unintended, unusual, and unexpected capacities for change—some would term "externalities"—that may not become apparent until well into the deployment process.

Figure 3 depicts the cumulative character of the two sources of change. On the left (T1) represents an ongoing system involving two technical organizations (Tech 1 and Tech 2) over-seen by a set of regulators. A new technological opportunity (New Tech, small circles top-left) emerges. As it is deployed into the society, some deployment strain (DS) is experienced if changes in institutional rule are effected to facilitate its development. When the deployment is "successful," resistance to institutional changes, such as altering building codes, means of financing, etc., will be overcome. These changes become part of the legacy of "technological change." Many are likely to persist, adding to the "amount" of change triggered by "the technology's" new capacity (NC) as "it" becomes fully integrated into both production and regulatory systems (T2). Analytically, both types of change (DS + NC) require specification if the full range of "impacts" is to be taken into account for policy study or technology assessment purposes. (Oddly, combining these two sources of "impact" is rarely evident in either policy analyses or technology assessments in the literature.)

Some technologies—one senses there is an increasing number— enter society gracefully, but begin to take on ominous properties as they are more and more widely deployed. "Externalities" cumulate so that when the technology emerges full-blown, "deferred regrets" become evident. For advanced industrial countries, and some developing ones as well, a clear case of such

FIGURE 3

Two Sources of Technology and Social Change



DS = Deployment Strain (DS)
NC = Effects of New Capacity (NC)

"deferred regrets" can be seen in regions dependent upon the automobile. Noxious emission particles accumulate to become severe air pollution; mobility often results in widely dispersed residential areas; movement often becomes restricted and frustrating in daily traffic congestion. These effects are recognized *regretfully* as unfortunate but nearly irreversible conditions associated with a technology upon which the region has come to dependent. And to depend so deeply that it is hard to imagine an alternative or that the region could stand the costs of a substitute technology with fewer or perhaps different "deferred regrets."

There are, obviously, many examples of shorter-term conflicts associated with forced entry of a new technology.[18] And there is a growing awareness that some gracefully entering technologies may result in deferred regrets. *Examining new technologies, or those in mid-stages of deployment, in search of those that would be seen with increasing regret—were they fully deployed—are very important act activities for technology assessors and policy analysts.* But the literature does not provide us systematic means to anticipate various beneficial or potentially regretful effects in particular technological areas. Yet, we now know to anticipate often immediate changes associated with programs of forced entry, and many people are haunted by potentially regretful outcomes of technologies that are promoted rapidly to full scale. Without more careful analysis of these two sources of change, continued "free-floating" political anxiety—and with it conflict—about technologies and the social future is likely to intensify.[19]

Utilizing Socio-economic Advantage. The third source of effect, the behavior of the organizations that produce and distribute new technical capacities (Figure 2, Arrow III), has attracted little systematic attention in studies of technology and social change. There has been almost no attention paid to such matters in technology assessments. These organizations seek economic and operational advantages, through the political process at national, state, and local levels, that will make their work more profitable and easier to conduct. Staying with our air transport example, we see the aircraft industry lobbying for public subsidies and tax allowances. Airline interests pressure both national and local bodies for preferential treatment in airport location, landing fees, and routing. Airline employee unions attempt to upgrade their working conditions and salaries. Strikes and work slowdowns by airline personnel and air traffic controllers illustrate the kinds of pressure on local government and agencies that accompanies the improvement of air transport capabilities, as well as the growing complexity of the national air traffic system.

These activities are of a piece with attempts by promoters or opponents in the earlier and more precarious stages of technical development to alter the social and political context into which the technology is being introduced. And their salience for policy and social impact analysis increases markedly as the technology grows in scale, i.e., as the number of people involved grows, and especially as the interdependence among public agencies and private firms draws tighter.[20]

Figure 4 arrays the foci of analysis arising from our perspective thus far. The several sources of effect require explication *prior* to estimating the "second order" changes *if analysis is intended to enlighten a wide range of changes potentially to be experienced as a consequence of approving and supporting a technology for full-scale deployment.* Characterizing or describing the technology, in terms of its social properties, is a crucial "first step" for more credible estimates of longer-term social effects. It is also one that is rarely attempted. In a recent review of a number of technology assessments conducted by the Office of Technology Assessment, none of the studies included anything nearly approximating the specifications of technologies discussed above.[21] It is not difficult to see that more complete descriptions of likely changes and requisites would be resisted by some promoters, while some opponents are reluctant to elaborate the full range of enconomic beneficiaries. At the same time, to take up the analytical tasks implied here is a daunting prospect, especially in the context of the usual conduct of policy studies or technology assessments. The data requirements implied above and discussed below are formidable, rarely available independent of work specifically devoted to generating them, and likely to be time consuming in aggregation. All this in the face of demands by the clients of the analysis for rapid results...often for the purposes of the promotion of views already fixed, which do not readily countenance contradictory analysis. Policy analysis is not an

FIGURE 4

Focii for Social Analysis

SCALE OF DEVELOPMENT	Sources of Social Impact: Altered Institutional Conditions	Widespread New Capacity	Behavior of Successful Deployers
Early Deployment	Important precedents for future	(Not yet relevant)	(Not yet relevant)
Later Full Maturity	Changed institutional structure	Changes in citizen & firm behavior	Changes in political situation

easy business. But when it is done *as if it were more or less complete,* it is justified to expect an explicit recognition of the conceptual and data demands of the enterprise.

In the next section, we examine in more detail the data requirements for a social characterization of technologies; keeping in mind the social setting of technical deployment and the aim of identifying early indications of deployment strain and potential deferred regrets.

Enhanced Social Characterization of a Technology

More accurate analyses of impact, benefit, or risk requires knowledge of or credible assumptions about the changes necessary to nurture a new technology, and what its widespread deployment would mean: first, in terms of its direct effects, locally and nationally, upon employment, capital spending, and dislocation of or advantage to existing economic and political interests, and second, in terms of the subsequent reactions to these initial changes, especially as the network of facilities involved expands to full operational maturity. This section outlines an approach which would fill many of the existing gaps in information and knowledge essential to the analytical phase of technology assessment, and public policies involving significant technological elements

Four types of data are needed for improved estimation of social effects: (1) functional descriptions of the activities required to establish, deploy, and operate various steps in the technology; (2 and 3) identification of the resources and social requirements for realizing each function for each step; and (4) for the politically important class of technologies which are *benefit-rich but hazardous,* a clear specification of the technical and operational "extras" necessary for the technology to operate at very high levels of reliability.[22]

Functional Elements. In deploying most new technologies, four functions must be carried out; for "risky" technologies, two more would be added. The four customary ones include: the *construction* of the facilities and the transport links between them, if they are not already in place; the *operation* of these facilities once constructed; the *transport* and movement of the key feed stock, products, or other essential movables within the system; and the *administrative* *oversight* and coordination of these activities. The special risk-related nature of some technologies, such as the handling of radioactive waste, prompts two special requirements: continuous attention to *assuring the reliable, nearly failure-free operation* of the system, and the *provision of security* for internal systems and external approaches to guard against intentional, harmful disruptions. The specific technical character of these six functions varies, of course, as a consequence of the particular design options chosen and the strategy employed for deployment.

The next steps are to develop an *estimate of resources* necessary to realize each function at desired levels of reliability, and an analysis of the *social properties of the organizational systems* likely to be developed to meet these performance objectives. In effect, we need carefully calibrated measures of the social stimuli that prompt the immediate changes from which management challenges issue and social changes result. What categories of social and economic data should be collected, how should they be organized in this most necessary, and least carefully done segment of technology assessment? The matrix shown in Table 1 arrays the functions outlined above with more detailed sets of resources and social categories that characterize each major step in the technical process.[23]

Resources Requirements. The resource categories employed here—capital investment, operational costs, logistics, and labor force—are frequently used in contemporary policy analysis and technology assessments, although not fully related to the functions noted above. The first two, *capital investment* and *operating costs,* should be estimated in terms of the sums necessary for each year or two during the life of the various facilities involved; the amounts and proportions of payroll likely to be disbursed through local facilities, as contrasted to facilities elsewhere in the system; and money likely to be spent locally for equipment and services, compared with that likely to be spent outside the region. Equally important, but more difficult to estimate, are the likely sources of financing capital investment and running costs as the system grows to large scale. Of special interest are the proportions of income likely to be required from public funds and from private sources or users.

Estimates are also necessary for the *logistical requirements* and material needs for each function as various technical steps are expanded. Both the material and the natural resources potentially threatened by short supply as the technical system grows to full maturity would be identified. Are rare metals needed? What requirements for special transport facilities or vehicles are likely?

Labor force. requirements should be calculated in terms of the total number of workers likely to be necessary. The ebb and flow of their number and occupational mixes, both locally and nationally, are of special interest as the various stages of deployment and scaling-up to a national system are carried forward. These data, together with payroll and capital investment information, provide an essential element in estimating local and national economic impacts.

Social Characteristics. Other information, not usually included in the estimates for industrial planning, is also necessary: first, the mix of *occupational skill levels*—skilled, semi, and unskilled—possessed by the employees and management of local facilities, permit an initial estimate of the social influences likely to extend into communities and regions with the advent of new industrial operations. Though difficult to calculate, when the actual locations of industrial facilities have not yet been fixed, estimates of the likely dispersion of housing for workers who come from the local labor force, as compared with those brought in from outside, gives an indication of the potential benefits and/or strains for the communities affected.

Second, and of particular interest with regard to "risky" technologies like nuclear power plant operations, air traffic control, or radioactive waste handling, is an estimate of the character and costs of the *training efforts* necessary to assure reliable, consistent performance in operating the various components of these technologies. At present, there are few systematic attempts to make such estimates, although some lessons can be drawn from the training and safety experiences of the Air Force's ICBM forces, the U.S. air traffic control system, and the large-volume processors of toxic chemicals like DuPont and Dow Chemical.[24]

The character of the *administrative systems* designed to coordinate and control a growing number of facilities, transport links, assurance and surveillance systems, is also significant. As the number and size of "components-to-be-coordinated" increase, so often do the scale and internal complexity of the administrative system developed to accommodate them. Increases in administrative complexity, a key source of operational error, will vary from function to function, and from step to step in a long-linked technical process.[25] The costs of control measures and the difficulties of assuring rigorous administrative oversight without loss of flexibility are important for gauging the implications of potential regulatory reactions, especially for those technologies that demand nearly failure-free performance.[26]

Finally, estimates of the *complexity of the networks* of the facilities, transport, and quality assurance/security activities needed for system operations—though rarely available for descriptions of large-scale technical systems—signals the probable level of regulatory demand prompted by the technology. The more complex these networks, and the greater society's stake in their effective, reliable operation, the more likely the pressure for external regulation. This is of particular importance for "risky" technologies. For instance, the dispersion and density of a national, or perhaps international network, encompassing nuclear reactors and other sources of radioactive waste, their storage and processing facilities, will vary, depending on the particular alternatives for final disposal actually implemented. Very likely, these would lead to different regulatory and operational consequences as well.[27]

Requisites for High Reliability. For technical areas where significant operational errors result in bearable consequences, and where trial-and-error learning can be a useful, cost-effective tactic, further analysis is probably unnecessary. But for benefit-rich/hazardous technologies, the usual process of successive approximation—on the basis of errors made and then corrected—cannot command great enthusiasm. The consequences of such errors may be so egregious and potentially catastrophic that learning from them would be a very dubious strategy for "improvement." It is in cases such as nuclear waste management and the nuclear fuel-cycle more generally, and genetic engineering, that additional painstaking analysis seems warranted. This is the detailed specification of the *technical and managerial processes* proposed, so that estimates can be made of the potential for reduced reliability and/or significant error if the technology is *widely deployed on a large scale.*[28]

In the case of nuclear waste management, the long-linked and relatively complex character of the technical and managerial processes necessary to deal with military and commercial wastes markedly increases the challenge of providing the information needed for credibly estimating the costs and effects of their safe disposal. No matter which options are chosen for nuclear waste handling and emplacement, they will be highly complex. There may be significantly different collection and handling processes for various types of waste produced by mining and milling fuel stock, fabricating fresh fuel, burning it, removing the residual spent fuel, and decontaminating the affected plants and facilities. Systematic processes are also required for transforming original wastes into forms which can be solidified and then emplaced forever. Of course, both transport and security are interwoven with the primary processing and emplacement steps. Using the spare matrix in Table 1, the information characterizing the particular functions of each step could be arrayed for a technology, e.g., the entire waste management process or a new generation of air traffic control communication and control technologies. This done, planners and citizens alike would have a better basis for estimating the costs actually involved and understanding the probable effects. Attention to "risky technologies" is critically important. They are becoming a source of mounting anxiety among able citizens, especially those worried about the longer-term, potentially irreversible and significant consequences of errors that characterize some benefit-rich/ hazardous technologies. If the suspicion of a potential for long-term, incipient error, involving very onerous consequences, intensifies, political conflict will grow—conflict that is itself an important social effect.

Describing technologies in terms of their social properties and operational categories enables us to render technical processes in terms that can be linked to the reasonably well developed fields of the social sciences. Such explication of technical elements of particular public policies is necessary if analyses concerning their consequences are to be accurate and rise above impressionism and documents of persuasion. At this time, neither descriptions nor con nections are available to harried analysts or to scholars. This paper encourages the first; a subsequent effort

TABLE 1

Activities and Resource/Social Requirements Matrix for Each Phase

		Functional Elements					
		Const.	Oper.	Trans.	Admin.	Assur.*	Sec'ty.*
		(1)	(2)	(3)	(4)	(5)	(6)
A. Resource Requirements							
Capital Investment	(1)	a_{11}	a_{21}	•	•	a_{51}	a_{61}
Operating Costs	(2)	a_{12}	•	•	•	•	•
Logistics	(3)	a_{13}	•	•	•	•	a_{63}
Labor Force	(4)	a_{14}	•	•	•	•	a_{64}
B. Social Requirements							
Skills Profile	(1)	b_{11}	•	•	•	•	b_{61}
Training Programs	(2)	b_{12}	•	•	•	•	b_{62}
Admin. Complexity	(3)	b_{13}	b_{23}	•	•	•	b_{63}
Network Properties	(4)	b_{14}	b_{24}	b_{34}	•	b_{54}	b_{64}

* Benefit rich/high risk technologies only.

addresses the connections.

Notably, it is difficult to find good examples of what we urge. Our injunctions are logically unassailable. But as a practical matter, following them is most demanding, requiring greater rigor than present resources can sustain, especially at the level granting or contracting agencies have been willing to consider. But meager resources is no reason for avoiding discussion of the conceptual and data requisites for acute analysis.

NOTES

1. K. Arrow, "Social Responsibility and Economic Efficiency," *Public Policy,* 21 (Summer, 1973), 304-317.

2. See J.K. Fiebleman, "Pure Science, Applied Science, Technology, Engineering: An Attempt at Definitions," *Technology and Culture,* 2 (Fall 1961), 305-317; and C. Mitcham and R. Mackey, eds., *Philosophy and Technology* (New York: Free Press, 1972); C. Susskind, *Understanding Technology* (Baltimore: Johns Hopkins University Press, 1973); and N.B. Hannay and R. McGinn, "The Anatomy of Modern Technology: Prolegomenon to an Improved Public Policy for the Social Management of Technology," *Daedalus,* 109 (Winter 1980), 25-54. Cf. L. Winner, "Technologies as Forms of Life," in R.S. Cohen and M.W. Wartovsky, eds., *Epistemology, Methodology and the Social Sciences (Reidel, 1983), 249-263.*

3. See D.P. Billington, "Structures and Machines: The Two Faces of Technology," *Soundings: An Interdisciplinary Journal,* (Fall 1974), 275-288, for a discussion of the different implications of these two types of physical objects for political and social criticism. Cf. W.L. Garrison, "Thinking About Public Facility Systems", in National Academy of Science, *National Research Council in 1980's,* Commission on Socio-technical Systems, Washington, D.C.: National Academy of Science, April, 1978), 244-265.

4. T.R. La Porte, "Beyond Machines and Structures: Bases for the Political Criticism of Technology," *Soundings, ibid.,* 289-304.

5. See especially L. Winner, "Artifacts Have Politics," *Daedalus,* 109 (Winter 1980). Also, L. Marx, "Technology and the Study of Man," in W.R. Niblett, ed., *The Sciences, the Humanities and the Technological Threat* (London: London University Press, 1974); L. Winner, *Autonomous Technology; Technics-Out-of-Control as a Theme in Political Thought* (Cambridge, MA: MIT Press, 1977); Hannay, *op. cit.*

6. Early work at the Tavistock Institute in England explored the technology/organizational relationship. See, for example, F.E. Emery and E.L. Trist, "Socio-Technical Systems," in *Management Science Models and Techniques,* Vol. 2 (New York: Pergamon Press, 1960); K.D Greene, *Social-Technical Systems: Factors in Analysis, Design and Management* (Englewood Cliffs, N.J.: Prentice-Hall, 1974). Subsequent work in the U.S. is summarized in W.R. Scott, *Organizations: Rational, Natural and Open Systems* (Englewood Cliffs, N.J.:Prentice-all, 1981), ch. 10; Cf., G.M. Dobrov, "Technology as a Form of Organization," *International Social Science Journal* 13 (April 1979), 585- 605; R. Kling and W. Scacchi, "The Web of Computing: Computer Technology as Social Organization," *Advance in Computers,* Vol. 21, (New York: Academic Press, 1982), 1-90, esp. 71-85; and J. Fried and P. Molnar, "A General Model for Culture and Technology," *Technology Forecasting and Social Change,* 8 (1975), 175-188. See, J. Hiner "On Distinguishing 'A Maachine' from Its System, *American Quarterly,y,* 31 (Winter, 1961-62), 51-69, for an earlier argument separating artifact from organization.

7. An earlier version of these notions was used as a basis for field research in T.R. La Porte, et al, *Interactions of Technology and Society: Impacts of Improved Air Transportation—Study of Airports at the Grass Roots* (University of California, Berkeley, Institute of Governmental Studies, for Ames Research Center, Dec., 1974); issued as NASA Contractor Report CR-2871, Washington, D.C., July 1977.

8. See especially the excellent summary, P. Kelly and M. Kranzberg, eds., *Technological Institutions: Critical Review of Current Knowledge.* (San Francisco: San Francisco Press Inc, 1978).

9. See H. Sapolsky, *The Polaris System Development* (Cambridge, Mass.: Harvard University Press, 1972), and S. Zweriing, *Mass Transit and the Politics of Technology* (New York: Praeger, 1974), for examples of studies of the politics of technical choice.

10. I am grateful to John Andelin for this felicitous phrase.

11. Discussion of types of "entry" and subsequent consequences in this section owes much to talks with Gene Rochlin and Ted Bradshaw.

12. See Zwerling, *op. cit.,* Note 8, for a description of such changes during early stage of the San Francisco Bay Area Rapid Transit (BART) system development. For an example of the "scale-up" process, see F.B. Sprow, "New Sources [of Energy] and their Technological Prospects," in M. Held, coordinator, *Proceedings of the Exxon Energy Research and Development Symposium: Science, Technology*

and the Energy Transition, May, 1981. (Florham Park, NJ: Exxon Research and Development Co., 1981), 37-39.

13. For a rare attempt, see D. Noble, *American by Design,* (New York: Oxford University Press, 1977).

14. U.S. Congress, Office of Technology Assessment, *Technology, and Steel Industrial Competitiveness,* (OTA-M-122), (Washington, D.C.: June, 1980).

15. There are numerous reports and many expose' describing the political activities of industry. However, few of these attempt systematically to explicate the relationship between technological developments and the industry's social powers. A review of much of the writing concerning the methodology of technology assessment turned up *not one* discussion of these sources of change.

16. See especially U.S. Congress, Office of Technology Assessment *Radioactive Waste: Summary of Findings,* (OTA-0-172), Washington, D.C., April, 1982.

17. La Porte, *op. cit.*, note 7.

18. See especially A. Mazur, *The Dynamics of Technical Controversy* (Washington, D.C.: Communications Press, 1981); 19. D. Nelkin, ed., *Controversy: Politics of Technical Decisions,* (Beverly Hills: Sage Publications, 1979), summarizes a dozen such controversies. See also M.E. Ames, *Outcome Uncertain: Science and the Political Process* (Washington, D.C.: Communications Press, 1978). and E.W. Lawless, *Technology and Social Shock* (New Brunswick, N.J. Rutgers University Press, 1972).

19. See A.G. Levine, *Love Canal: Science Politics, and People* (Lexington, MA: Lexington Books, 1982).

20. T.R. La Porte, "Nuclear Wastes: Increasing Scale and Sociopolitical Impacts," *Science* 191 (July 7, 1978), 22-29.

21. The studies reviewed were selected by the Office of Technology Assessment as representing the various types conducted by this agency. See T.R. La Porte, "Technology as Social Organization: Toward Improved Technology Assessment" Paper for the Task Force on TA Methodology and Management, Office of Technology Assessment, Sept. 1981, for a critique of these studies based on the notions discussed herein. For other papers contributed to this task force, see the special issue *Technological Forecasting and Social Change,* 22 (Dec., 1982).

22. La Porte, "Nuclear Wastes: ...", *op. cit.*

23. While precise estimates are often difficult to establish with great confidence, upper and lower bounds can be. Subsequent analysis, then, should include the likely impacts, were the actual situation to approach one bound or the other.

24. Cf. C. Perrow, *Normal Accidents: Living with High Risk Technologies,* (New York: Basic Books, 1984), esp. "Complexity, Coupling and Catastrophe," Ch. 3.

25. C. Perrow, "The President's Commission and the Normal Accident," in *The Accident at Three Mile Island: The Human Dimensions,* (Boulder, Colorado: Westview Press, 1981), ch. 16.

26. See T.R. La Porte, "In Search of Nearly Error-Free Management: Lessons from U.S. Air Traffic Control for the Future of Nuclear Energy," paper presented, Woodrow Wilson International Center for Scholars, Washington, D.C., 14 November, 1980.

27. National Academy of Sciences *Socioeconomic Aspects of Radioactive Waste Management,* report of the Panel on Integrating Socioeconomic Criteria into the Selection of a Geological Repository for the Disposal of Radioactive Waste, 1984 (especially Ch.4); T.R. La Porte, "On the Design and Management of Nearly Error-Free Organizational Control Systems," in D. Sills, *et. al.*, (eds.), *The Accident at Three Mile Island: The Human Dimensions, op. cit.;* and T.R. La Porte, "Managing Nuclear Wastes, "*Society,* 18 (July/August 1981), 57-65.

28. La Porte, *op. cit,* note 26.

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