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In a time when decision making about "technology" is almost certain to become a major political topic, it is crucial to refine our thinking so that technology will be understood in terms more susceptible to public debate. Our present language for technology has reached a remarkable degree of technical and mathematical refinement...refinement so powerful and precise that when technologists are provided great organizational and political resources, they reduce the impossible to the commonplace. Thus, this nation has come to witness space flight as ordinary and to await, with little awe, nuclear generation of energy. Yet the language in which we speak of technology is truncated and unbalanced. Its terms are hazy and its concepts often slovenly when applied to technology's impacts upon the lives of citizens and consumers. Such imbalance is unfortunate, perhaps dangerous, for technical precision and power tend now to obscure the deep social consequences which technological development holds for us all. Professor Billington's "Structures and Machines: The Two Sides of Technology," is a welcome attempt to develop a way of perceiving technology so that its social and political implications are rendered more apparent. In making a distinction between machines and structures, linking them to different properties such as change and permanence and mass production and craft and then associating each of these properties with different public criteria for evaluation, he has pointed to three sources of confusion in our current thinking about technology as it affects the commonweal.

The most serious confusion arises from an implicit conception of technology that covers a staggeringly wide range of undifferentiated phenomena. An enormous variety of technologically spawned devices and physical structures is gathered under the term "technology," defined as the application of scientific principle to the solution of socially defined problems.[1] While the technical or scientific logic of this classification is understandable, further conceptual refinements remain undeveloped. This lack of discrimination is Professor's principal objection, one he addresses directly with his distinction between machines and structures. Without such a distinction, we have no way of treating such things as television sets and roads, kidney machines and nuclear power stations, and computers and airports as having important systematic differences. To be sure, all of those things are "technology," but that designation is so all-encompassing that without further refinement we are tempted to treat them as if they had similar social or political properties. To do so seems clearly in error, and, brought (unconsciously or not) into policy considerations, such treatment would lead to policy mistakes.[2] One consequence of this kind of confusion is an implicit bias in most policy literature toward technology-as-machine. While Professor Billington's insistence upon a parallel concept of technology-as-structure is clearly in order, additional distinctions are also necessary.

The initial confusion leads to a second: a muddled and far too simplistic sense of the social properties characterizing various technological devices and/or structures. Without a way of distinguishing various types of technology, there is no reason to expect a very refined systematic understanding of the social, organizational, and economic consequences likely to follow from the construction and implementation of various new or improved technologies. Again, Professor Billington's article speaks to these questions, though in a less consistent and systematic way than it does in distinguishing machine from structure. Other work has been done on this aspect of understanding the relationship between various technologies and social experience, but it is not well advanced.[3] In the absence of distinctions which allow a systematic linking of technologies to varieties of social experience, we are left with relatively inchoate impressions about "what will happen if...: if a big nuclear power plant is actually built along the seacoast; if a freeway really cuts through a ghetto; or if widespread dissemination of biological engineering techniques which can determine the sex of an unborn child really occurs. Nor do we have a clear sense of the social or economic consequences of public funding as against private funding of new developments, especially as this difference is applied to various types of technology.

In our optimistic stimulation of technological development, initially through the market system and later through military procurement practices and space development, we have assumed that whatever was developed would enhance the general good. If technological development produced any unfortunate consequences they were likely to be greatly offset by the new capability. As long as this happy trade-off seemed to be the case -- and it did seem so for a number of decades -- there was no compelling reason to investigate systematically the varieties of social and political impacts of different technologies. In this climate of optimistic expectation, we have managed to avoid developing the kinds of knowledge and information that could aid us in understanding how machines or structures shape individual and social behavior. For example, while there is often an intuitive sense that the character of the structures in which we live and work has an effect on the patterns of personal relations we develop, there is little _systematic_ knowledge of how this interaction operates or how it could be altered. The same is true for the variations in the design of the machine-structure of factory production systems and their apparent penchants to increase or attenuate the feelings of alienation experienced by the system's "human parts."

While this absence of knowledge about most, perhaps all, social structures is our lot, it is particularly difficult in regard to technology, one aspect of the world which we do purposefully change.

A final confusion issues from the other two. Contradictory criteria or values are mingled with inappropriate "policy analysis techniques" and applied to technologies, treating different ones as if they were quite similar in design and consequence. Thus, the analytical tactic of cost-benefit calculations is applied widely to many different technological projects whether or not the desired benefit or social costs they imply are amenable to the numerical analysis. And the criterion of "efficient" production is applied to both machines and structures often with little regard for indirect social and environmental costs -- sometimes termed "externalities" by economists. While in general machine technologies are appropriately evaluated through such techniques, many machines and most structures are intended to advance social, political, and cultural conditions that resist reduction to mathematical sums. Thus, the criteria of community or of aesthetic effect confound the quantitative formulae of cost-benefit techniques. Professor Billington is certainly concerned about this problem. In large measure the major thesis of his paper is to nominate architecturally grounded aesthetic and artistic values as major criteria in making decisions about structural projects. Oddly, what seems missing, at least from the vantage point of the social sciences, is a complementary emphasis on the social effects of large structural projects in terms of the opportunity costs they incur simply because they tend to be so expensive. But more of that shortly.

"Structures and Machines" advances several steps toward reducing the confusion on all three counts; this essay-in-response attempts to extend the effort. It is written from the perspective of an interested and sympathetic observer rooted primarily in the social sciences and is intended to supplement, not displace.

Technology As-Social-Organization

In "Structures and Machines," technology-as-physical entity was partitioned into two major types, each having different properties such as size and permanence and different planning and economic tendencies. These are helpful distinctions, but they exclude a good many of the catalytic and active aspects of technology that trigger social changes. Billington's technology-as-physical-entity needs to be joined by the notions of technology-as-social-organization. Two further distinctions are thereby enabled which may help us to link the physical manifestation of technology with its social and human consequences. These distinctions are, first, the new social capacities delivered by new developments and, second, the organizations of producers, builders, distributors and maintainers of both structures and machines.

New or improved machines or structures provide new or improved capacities for consumers and citizens. For example, advances in automobile technology provide more efficient travel and/or more engine power for speed or for cargo capacity; improved freeways increase the volume of traffic possible and reduce congestions; and great public buildings often prompt a closer coordination of government affairs and sometimes improve the access of citizens to those who make decisions affecting their lives. Whether these new capacities are believed to be in the public interest or not depends in part on the value of the familiar activities enhanced by the development and in part on whether the new activities take on positive value when accomplished through the assistance of a new machine or structure.[4] This latter aspect of new capacities raises the most interesting social and political questions, and it is around this problem that most of the issues surrounding the politics of technology are likely to center. It is one thing to support the development of a technology which increases the ease of doing familiar things. It is quite another to support a development which introduces a new, unfamiliar capacity, such as traveling at supersonic speeds, determining the sex of the unborn, or constructing an unusual configuration for a massive building, with the rationale that the public will come, in the future, to appreciate and value its uniqueness.

But beyond these rather direct relationships to the lives of consumers and citizens, machines and structural developments introduce another strong, albeit indirect, influence on our lives, particularly when these developments are of large scale: the economic and political power of the organizations and their leaders which produce, distribute, operate and maintain machines and structures. In a sense, the people who inhabit these organizations are the social manifestation of technology...they are technology personified. There are countless people whose livelihood and whose sense of occupational identity are bound up with the development of one technology or another. These people include the engineers who design the structures of travel or habitation, the men and women "on the line" producing the many machines of our culture, and the leaders of the manufacturing enterprises whose social and political power is buttressed by the economic power of their technology-based organizations. The relations of these organizations to governmental bodies and to economic conditions affect us all indirectly, though nonetheless importantly for the indirection. How the U.S. military, the American Medical Association, General Motors or Standard Oil enter into the process of government can increase or decrease its effectiveness in enhancing the lives of its citizens. And it is through such organizations that modification in the design both of structures and of machines must be routed. A clearer focus on the social organization of technology is necessary before we can move very far toward the uses of technology so engagingly suggested by Professor Billington.

The organizations that produce and distribute machines range from relatively small-scale manufacturing firms to such giants as General Electric, IBM, and the auto manufacturers. The machines such firms produce are, as Billington suggests, more adaptable to changing conditions than are structures. But as the overall size of a producing firm grows, the costs to them of making mistakes in changing models rise greatly as well. Mass produced mistakes can be as costly as mass produced profits can be huge. Hence the sociological adaptability of mass producers of machines is often a good deal less than it may first appear. This means that the planning horizons of machine makers may approach the planning horizons of structure builders. It also suggests that in certain situations there is a kind of sociological inertia associated with machines that is akin to the physical permanence associated with large structural projects. The difficulty of changing the internal combusion engine may be as great as undoing the aesthetic detriment of many freeway projects. Massive wrecking operations must be mounted in both cases, in one the destruction of concrete, in the other the destruction of occupations.

Organizational size has a similar social effect to that of the massive physical scale of many structures: the properties of technology-as-physical-entity and as-social-organization require the alteration of individual behavior in accord with the "needs" of the technology or the organization. Our behavior is shaped, for example, by the ribbons of freeway leading, with little deviation, to town after town. Advertising campaigns of General Motors prompt the public to alter habits by urging it to consider a range of alternatives in fact narrower than many desire. The range of consumer choices is as often constricted by large producers of machines as it is expanded.[5] And the contracting organizations of structural technologies also affect us on sociological and political levels. Thus, in much the same way that the large producers of machines have sought favored places in the various hives of governmental regulations, the Corps of Engineers and many state highway departments have for some time assiduously cultivated the support of important political groups so that they could do their "technological thing" relatively exempt from consideration of environmental values. In effect, this is the coupling of the physical permanence of structures with the political permanence of government sanction and official power. When this sort of "double whammy" occurs certainly both increased political watchfulness and care in planning is crucial.[6]

The manner of financing technological development is another important element in determining the kinds of political criteria to be used in making judgments about the effectiveness of a particular development. Technological projects funded mainly by public monies tend to be judged according to a much wider range of criteria than are privately financed projects. As Billington suggests, there is a seemingly analogous relationship between public financing for structural technology and private backing for machine development. But upon closer inspection we see important exceptions, some of them widely prevalent. The public funding of machines is visible especially in the military and transport areas. The machinery of war, automatic weapons, aircraft, electronic devices of all sorts are produced almost exclusively with public funds. The same is often true for both bus and rail-based mass transit systems, and certainly the development of those most sophisticated of machines, the moon landing vehicles and the Skylab space stations, has been supported by public funds.

Similarly, much structural technology is often built at the behest of private development. Indeed, a great deal of the political ferment about environmental and urban blight which has been prompted by structures concerns privately financed massive power plants encroaching on former open space, huge corporation towers crowding the skylines of many central cities, and the monotonous ugliness of privately developed housing tracts sprawling between towns. Yet these examples do not gainsay Billington's major thesis, for these privately funded structures have an effect parallel to the massive public developments of airports, flood control dams, freeways, public housing developments, and the military and space launching complexes looming surrealistically on countryside horizons. The public vs. private funding distinction has been an important basis for different public judgments about the norms of technological development; it has also been at once useful and deceptive.

Until quite recently, we believed that very different political criteria should be applied to projects which are privately financed as against those supported by public funds. If technologies were adaptable and if their ducers were responsive to consumer values through a well functioning market system, perhaps then the public could afford the luxury of being a disinterested observer of industrial development; for under those conditions it would seem to result in one wonder after another. But the political criterion of private autonomy makes sense only if a reasonably effective self-regulating mechanism operates capable of accounting for and pricing the indirect effects of technological production. When the social organizations of technology, whether private or public, become very large and very complex, all of our existing "institutions of regulation" begin to malfunction. Whether structure or machine, whether publicly or privately financed, the degree to which technologies and their production/distribution organizations are adaptive or coercive marks the final distinction crucial for improved political criticism of technology.

Technologies: Adaptive and Prescriptive

Billington's insistence that some technologies are more adaptable than others is clearly sound. Dams and freeways are virtually permanent structures which cannot, without great effort, be changed in response to changed economic or social conditions. On the other hand, the use of computers varies remarkably from firm to firm and instance to instance. Recently a reduction in enthusiasm for computerized data processing has been evident in some organizations; and certainly the public anxiety about the invasion of privacy threatened by data banks is apt to modify computer use substantially.

Political concern arises from the uncertainty of whether machines and/or structures can be adapted to changing social needs or whether, on the other hand, their backers will come to coerce people and communities into changing their behavior in order to utilize those technologies. Adaptive technologies are shaped by human values; their producers respond to changes in social values and alter their design accordingly. Prescriptive technologies shape the development of both social values and public life.[7] The crucial distinction is that adaptive technologies rarely, if ever, embody a specific vision for the future political or social shape of communities. Thus, bus-based public transportation systems adapt to new or changing patterns of living; buses can go where the populations have gone before them or follow them if they go someplace else. Prescriptive technologies, on the other hand, do have an implicit image of future society embedded in their design. That is, they are designed and produced by men and organizations seemingly committed to generating specific future social conditions and community experience. Such technical systems are rooted in a kind of technology-based teleology. Thus, rail-based rapid transit systems, in contrast to buses, may extend into areas before high density population growth has occurred there; in a sense, the economics of this particular system almost requires that such growth does occur in order for the system to operate at its designed capacity. Public investment in such systems necessarily is very great; hence relatively high use factors are required for "efficient" operations. Therefore, large numbers of people are also needed, suggesting that sometimes people must be brought to the system rather than the system brought to them.

A quite explicit social vision informs the design of some prescriptive technologies. The shape and character of urban places envisioned designed by city planners and builders is a prime example. In almost every case the nascent social future or preferred society has been the creation of the designer, with little involvement of the people who are likely to <u>be</u> that future. In such cases, the "most desirable future" is defined by someone other than those people who will act it out within the new structures and through the new machines. More often than not, neither the designers nor the public is conscious of this covert definition of "the public interest." For the most part, technology is seen as relatively neutral in its impact on the social future. For neither the designers nor the public has much to draw on from available knowledge about the probable long-term social or political consequences of one type of technical design as opposed to another's. Yet in retrospect it is clear that many technologies have had an enormous effect on social and political experience. We know this in the negative sense mainly, after the fact, when we see the undesirable, sometimes horrendous, results of some large projects. Urban blight and environmental destruction are obvious examples. In more subtle ways, such consequences are also visible in developments in television programming and computerized work processes.

The apparent capacity of a technology and its particular organizational manifestation to shape the responses of large numbers of people in potentially adverse ways should be a matter of major political concern. A community or nation may find itself held hostage, in a sense, by conditions coming from past to commitments technological developments which embodied future social provisions. Such conditions may differ greatly from what the community experiencing them desires. It is this capacity of techno-organizational systems to prescribe and circumscribe the future which most disturbs many reflective people in a democratic society. In most cases where such prescription occurs alternative technological paths exist which could bring different social consequences from those made virtually inevitable by the prescriptive choice. But for lack of imagination or often a lack of resources, stemming itself from previous technological commitments, alternatives are not taken up. Large scale, costly technological machine-structural solutions to many problems of sustenance and commerce commit communities to courses that become for all practical purposes irreversible. In these cases, the opportunity costs (those opportunities lost due to irreversible physical change and financial limitations) can be exceedingly high and can exact payment from many succeeding generations. Thus, as the size of the techno-organizational system associated with any technology grows, the potential for social damage increases along with the benefits realized by the producing organization. Whether the sources of funds are private or public, the effects on the polity take on public proportions and open the way for changes in political criticism.

Bases for the Political Criticism of Technology

When several distinctions defining categories of technology are combined, they form a rough typology which could order relevant political criticism. Figure I presents the typology made by combining Billington's distinctions between machines and structures and between public and private financing of technological ventures with the adaptive/prescriptive distinction just discussed. Examples of each particular combination are included, and the reader is invited to add his own.

In a sense, the attempt to find illustrative technologies supports Billington's discussion of the properties of machines and structures. Publically funded, adaptive machines are rare; mostly military or NASA technologies. Similarly few privately funded, adaptive structures and prescriptive machines or publically funded, adaptive structures exist. However, a sufficient number of examples of privately funded structures and of publicly funded machines are evident, both of which have a sufficiently prescriptive character to warrant serious reservation about accepting Billington's structure/machine properties as they stand.

This typology can be used to suggest the distinctive social and political properties taken on by various technologies and different emphases in political criticism prompted by different combinations. The rest of this essay discusses the different types of technologies schematically depicted in Figure I and the variations in political/social criteria likely to be applied to them.

FIGURE I

A Typology of the Properties of Technology

Type of Funding	Social Character of the Technology: Adaptive		Prescriptive	
	Machines	Structures	Machines	Structures
Private	Automobiles Appliances Computers A	Prefab houses Irrigation ditches B	Jumbo jets Ships TV communication systems. E	Power stations Railroads Housing developments Assembly lines F
Public	Machine guns Radar Tanks C	Mobile air-strips Portable bridges D	Atomic bombs Spacecraft Kidney machines Rail rapid transit G	Airports Dams & Freeways Public housing Parks, Zoos H

Types of Adaptive Technologies. The most significant property of technologies for purposes of political understanding and critique is the degree to which the technology, in the way it is implemented, can adapt to reasonably immediate changes in consumer and citizen values, needs and preferences. That is, is the character of the technology and its implementing organization such that if consumers change their evaluation of its benefit to them the technology can be changed so that it is more in accord with consumer/citizen needs? The other major factor likely to determine the kind of public or political evaluation of a technology and its producing organization is the degree to which private funding, in contrast to public appropriations, supports it. In addition to public funds, public support includes the bestowal of political legitimacy. The importance of public funding is reasonably straightforward; salient examples of the bestowal of political legitimacy are the authorization of pharmaceutically pure ("USP") drugs and recognition of conformity to pollution control standards. The adaptive-prescriptive and private-public funding dimensions provide the bases for our first two types of technologies.

Type I points to the adaptive technologies, both machines and structures, which are privately funded. These technologies, exemplified in the upper left hand of Figure I (Cells A and B), draw the least political attention and the most straightforward application of political criteria.

In effect, performance in the market place is the primary criterion most often associated with such technologies. These are the technologies to which Billington accordingly assigns the criteria of efficiency and profitability. We also tend to include the criteria of functional utility and durability to such products, though there is little expectation that any mechanism other than the market should be used to insure product performance.

Our political response to this type of technology tends to be almost completely reactive; that is, political action with regard to them comes always after the products have been found wanting in some way or another. The most common reaction is to institute legal measures which will "make the market work"-- through anti-trust legislation, increasing consumer information about the products, and opening the courts to litigation enabling consumers to sue to recover damages due to false advertising, manufacturer negligence, etc. These regulatory constraints apply both to machines and to structures, with the additional constraints of building codes, zoning regulations and environmental impact analyses applied to structures. These political-legal measures attempt to insure quality of performance and limit the type of stuctures to accord with some definition of community interest.

More intense political scrutiny is levelled upon the adaptive technology, machines and structures supported with public funds (Type II cells C and D). Such technologies are found largely within the military and other massive industrially based government programs which necessarily operate outside the market system. Here the major criteria are public productivity and reliability, with some attention to efficiency of production. Most of these technologies are used in pursuit of some public goal, e.g., the common defense, national prestige, or public safety and health. These technologies are required to be reliable and effective when they are needed. Weaponry failure in combat is politically intolerable. So too are fire truck stalls en route to a fire, or electronic equipment break downs in the midst of an emergency. In essence, the political criteria of effectiveness and user safety are more important than the most efficient production of a machine, though there is, of course, an overriding concern that the public is not grossly overcharged. Furthermore, recent concern for environmental quality has been applied and has complicated the technologist's life considerably. Finally, with regard to publicly funded, adaptive technologies, there is a continuous concern that the sheer political power of the large private producing organizations does not influence governmental operation in such a way as to vitiate the conditions of equitable competition among private producers vying for exclusive governmental contracts, whether at federal, state or other governmental levels.

Types of Prescriptive Technologies. When technological implementation requires large scale developments, the reasons for political watchfulness multiply. If a technology's implementation demands that quite large organizations be established and/or that sizable portions of land be used, that technology becomes subject to commensurate political debate, whether or not it is financed by public funds; people and groups other than the direct providers of the technical capacity become involved: the prescriptive qualities of a technological development increase proportionately to the diffusion of its impact. To the degree a technology requires a long term change of personal behavior for its optimum performance, to that degree public concern should and often does increase. If a design for future development (of changed social experience) is implicitly embedded in technology, such concern is particularly called for. Thus we shall argue that as technologies, whether machines or structures, and their producing organizations, take on prescriptive qualities, and as they become the recipients of public funds, the most complex of political criteria should be applied to them.

The combinations of characteristics applied to adaptive technologies holds for prescriptive technologies as well. But in the following discussion the machine-structure distinction is considerably more important; consequently a more refined and elaborated typology will emerge.

Our next type (Type IIIa cell E) includes those <u>prescriptive machines which are developed and produced with private financing</u>. Very large jet air-transports, ocean-going ships, television and other communication systems and hugh earth moving machines are examples of this type. To be produced and made operational, these technologies require very large sums of money. (To insure that they are effectively used, often large structures are also adjunct to them.) Such huge investments make the cost of error correspondingly great. Thus the producers and operators continuously attempt to limit the great uncertainties often stimulated by unrestrained competition either by securing government subsidies or by making informal agreements among themselves. In the transportation and utilities fields, particularly with regard to technical R&D and often in operational matters as well, we clearly see such attempts. Subsidy of airline operation is a clear instance. For such prescriptive machine technologies, indeed for all prescriptive technologies, the market mechanism falters as the primary mode of adjustment.

Political criteria applied to such operations involve judgments about the degree of control exercised by the producing and operating corporations in setting prices and maintaining product quality and public safety. These criteria often run counter to the more profit-oriented goals of these corporations. Yet we are beginning to insist that such technologies, with their capacities to shape our experience, should be operated in the public interest. Public criteria must augment private ones. Industries that are associated with these technologies should be pressed to act as if they were confronted with a market condition which keeps prices down and quality up. At the same time, we seek to keep them solvent and in good order for they necessarily contribute to continued social development and military preparedness.

The political response to these massive, privately funded machine technologies is still largely reactive, though recently their producing organizations have become increasingly subject to government stimulated planning incentives. Regulatory agencies have been established, some many years ago, to monitor operator and producer activities: the U.S. Maritime Commission, the FAA and CAB for the airlines and aircraft companies, the watchdog activities of the FCC, etc. Such regulation is meant to substitute for the market mechanism in reducing costs to the consumer and maintaining public safety. Further, we want responsible use of public financial and political subsidies. Finally, there is an additional concern for the indirect effect on employment. Both the producing and operating firms employ large numbers of citizens, so corporate failures can result in severe hardships for local communities. Failure is relished neither by competitors nor by the government, for it raises the spectre of continued subsidies and/or public ownership. Many of these same criteria are applied to structures funded by the private sectors as well.

Type IIIb, noted in Cell F of Figure I, includes such massive, privately financed structures as power stations, railroad yards, road beds and stations, large housing developments, shopping centers, factory buildings and assembly lines. These kinds of developments are quite likely to require substantial changes in personal movement and behavior and are likely to shape the future of communities and political dynamics. Again, these prescriptive technologies cannot be brought within a market system of self-regulation. Thus the major political responses have focused around measures to counter a situation of very limited competition. Measures such as local zoning for control over land use and, more recently, environmental protection measures have become part of the difficult political elements facing those who would develop major housing projects and corporate high rises. These aspect of the politics of prescriptive, privately financed structure join all the others already associated with similar types of prescriptive machine technologies noted above in discussing Type IIIa.

Our final types, IVa and IVb, draw the most concern; for they combine social prescription with the massive resources of the public sector. These technologies shape social experience, doing so as they increase the direct tax burden of the polity. The effects of such publicly funded, prescriptive machines and structures on individual and collective experience are both direct and indirect -- direct through personal encounter and indirect through alterations on government's institutional function. We also attach to these technologies and to their producing organizations the widest definitions of public interest. It is likely that the effects of privately financed and operated prescriptive technologies have an equally important actual impact on our lives. But until we begin to see them as requiring the same relationship to the public control as those institutions supported by public monies and political legitimacy, we shall continue to expect less of them than we do of our governmental enterprises.

Massive machines produced through public funds (Type IVa, cell G) include some of the most dramtic technological achievements in human history. Devastating nuclear weapons; incredibly sophisticated and complex space exploration vehicles; devices, such as the kidney machines, prolong life; and, lately, the machines-structures of future transportation, rail-based rapid transit. Many of these dazzle us; others invoke dread. Nor is there any question that they require of us changes in our thinking, in our patterns of living, and in the shape of future communities. In many respects we know very little about the kinds of longer term effects these machine technologies will have, and our responses reamin often at the level of feeling and intuition. Hence the political reaction to these technologies is based on a mixture of attraction and resistance.

By and large publicly funded prescriptive machines are associated with military matters, national prestige and attempts to shape peoples' behavior--by moving us around or keeping us alive. While the more familiar criteria of productivity and efficiency are attractive, the consequences of these machines are difficult to measure in productivity terms. The enormity of these projects staggers the imagination, for sometimes they seem to assume proportions which challenge the kinds of human values held by the public. Finally, their environmental impact is so great as to raise serious questions about them upsetting finer relationships in nature's equilibrium. While we may cite the political criteria for evaluating and criticizing these technologies, usable processes of control have not been developed. They have not been, in part, because of the interfused military and civil character of the technologies. So far, military technologies have been well kept from public view; thus criticism of their detailed technical development has been impossible. But a more crucial limitation to exercising critical judgments about public technologies is the gross lack of information about the effects of particular technical designs upon social and political experience and governmental performance. Without such information, the essentially reactive regulatory stance now familiar for other types of technologies will continue and will impede progress toward regulation which, in order to stimulate socially desired purposes, focuses on the design of technologies and the practices of their producing organizations. Such a shift in focus represents a most significant challenge facing a nation newly concerned with the negative consequences of technological developments.

Reaction to prescriptive machine technology funded by government has been mainly exerted within the process of budgetary proposal and review. The sequence of budget proposals, hearings, and debates associated with the systems of weapons acquisition and planning for space developments through NASA has been designed to control technical development by means of fiscal limitations. But these activities are usually carried out within the producing or buying agencies themselves and reviewed by the Office of Management and the Budget and various Congressional Committees. Reviews inevitably have very limited technical and management knowledge of what choices really exist or what consequences might follow from alternative choices. The process of insufficiently informed review has been responsible, in part, for the apparent runaway spending in weapons development and, to a lesser extent, for the huge sums spent in the 1960's on space developments. Only recently have we begun to see retrospective revelations of gross mismanagement in the military.

And in the public's view, there is a growing sense that technological development has run amuck, that the time of low cost progress through technological development is over. Perhaps most responsible for this feeling has been the remarkable growth of "environmental consciousness." Oil spills and air pollution combined with the physical and social damage wrought by massive structural developments have aroused many in the public to question the automatic beneficence of technological development. Our last type of prescriptive technology, Type IVb, publicly funded structures (noted in Cell H of Figure 1), is subject to this general feeling and draws the greatest range of political criticism. Massive public works, such as airports like gigantic Dallas International in Texas, the huge flood control and hydroelectric dams seen throughout the Tennessee Valley, and large freeway systems, especially those forged through dense urban areas or formerly untouched wilderness areas all fall into this category; so do the publicly sponsored urban mass transit developments underway in the Washington D.C. and San Francisco areas and projected for a number of other cities. These systems are so large that they are likely to be major determinants of future social developments for their respective areas. And, since they are publicly funded, the full range of political criteria applies to them. All of the political criteria applied to publicly funded, prescriptive machine technologies apply to them as well. They also draw the recent political criteria of environmental protection, aversion to social dislocation of those most immediately affected, and finally, important standards of aesthetic effect discussed by Billington.

In a sense, the most interesting recent developments concerning the political criticism of technology, the establishment of the Environmental Protection Agency and the Office of Technology Assessment, have been focused on this type of technology. The advent of the Environmental Impact Statement requirement, now applied to the whole country and incorporated into State law as well, has opened up to the general public much of the information previously available only to the promoters of technology. All over the land citizen groups now have the information and the public arena needed to enter the adversary process before legitimate bodies such as city governments, state legislatures and courts, and importantly the Federal Courts.[8]

In the short span of several years this new access changed dramatically the relationship between the promoters and opponents of technological developments. Technology's promoters no longer can stand behind a veil of singular expertise; concerned groups can now have effective access to technical information and scrutinize apparently "objective" analysis. Considerable success has already been achieved in modifying the character of structural projects to reduce their destructive effects on the physical environment.

Finally, one of the most promising, very recent political developments has been the establishment of the Office of Technology Assessment, as an arm of the Congress. After a seven year gestation period, this office has been authorized by Congress and charged with improving the information available to Congress and the public concerning the environmental, economic and social impacts of potential technological developments. In actual operation only since the first of 1974, it is still too soon to judge how effective an effort this will be, although it is off to a promising start. The magnitude of the problems facing it is so great that dramatic improvement over the control of prescriptive technologies, whether machine or structure, should not be expected for some time. But it is possible now to anticipate reasonable progress in gathering the needed conceptual and informational background for much improved decisions about and monitoring of technological developments. The institutional frameworks are now available for the first time in our history. This development is paralleled by a growing awareness on the part of the public about the negative consequences of technology as well as its potential benefits. There is an additional sense that the regulation of technology is necessary and possible.[9]

Conclusion

In "Structures and Machines," Professor Billington ends his essay with an injunction that the secondary technology of machines[10]

> be kept as the servants of a primary technology of static, silent structures, planned, built and maintained for the common, balanced, equili-liberated (equal-liberated) peoples of our land.

In his view this subordination would increase the possibility that the aesthetic and humane sensibilities which underlie the development of great structures and which spread out to those who give them life might become the animating spirit of the future public support of technology. Such an ideal reflects the generous and hopeful vision of the designers of stunning building throughout history. Yet I do not believe that this idealism is shared by many of our present generation. The reasons go beyond contemporary perversity and dim vision.

The public debate, and to a large extent more scholarly discussion as well, regarding matters of technological decision making has not served us well, for it is still carried on in a language far too limited to advance much beyond trading vague assertions of grim doom or of over-optimistic prosperity. Both Billington's essay and this response to it attempt to speak directly to this limitation. And it is the task of such as read Soundings to take up the continual challenge in refining, perhaps inventing, a more balanced language of technology-for-the-commonweal.

During the decades of incoherent discussion, we have also been witness to dumbfounding changes prompted by new technological capacities. Furthermore, there has been voluminous evidence, past and present, of large technology-based oranizations, both in industry and government, engaging in short term economic and political profit to our egregious long term detriment. This has been the case with oil companies and the U.S. military, with General Motors and various state and federal road building agencies, with the Department of Agriculture and the White House offices of the Executive. Slowly the public is growing increasingly skeptical of the "technology-is-progress" idiom used by the domains of advertising for the technical communities. With this background of experience and without a suitable language for public discourse, no wonder an increasing wariness has emerged about the fruits of technology and about our national capacity to turn further development toward humane ends!

But as general uneasiness mounts, so too does evidence of changes which could bring technological issues nearer the center of political debate. Almost simultaneously there is a spreading recognition among American universities that this matter needs attention;[11] the public seems much more inclined to see technology as a potent, perhaps fundamental, political issue;[12] and Congress, through establishing the Office of Technology Assessment, has just provided an institutional channel into legislative mechanisms. Continued watchfulness will be needed, but there is reason to expect an improved possibility for the social guidance of technical development. What will emerge is uncertain, but whatever its form, it is quite likely to have a profound effect on our perspective of technology and on the manner in which we govern its development. It is likely to be so fundamental as to alter a good deal our familiar processes of governance. There are new potentials for bringing both the secondary technology of machines and the primary technology of structures within the bounds of a more humane public order.

NOTES

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1. This definition of technology is an almost universal one. For a cogent summary of various other perspectives, see C. Mitcham and R. Mackey, "Introduction: Technology as a Philosophical Problem," in Philosophy and Technology, Ed. Mitcham and Mackey (New York: Free Press, 1972), pp. 7-15.

2. A similar problem attaches to the way both the scientific and technological communities and those associated with science policy seem to conceptualize "science and technology." These closely associated terms encompass such a wide variety of phenomena and activities that without further distinction, discussion of science policy will continue to muddle along vaguely as it has for years, making little progress in understanding.

3. See the perspectives on technology used in J. D. Thompson, Organizations in Action (New York: McGraw-Hill, 1967; C. Perrow, Organizational Analysis: A Sociological View (Belmont, California: Brooks-Cole , 1970), esp. Ch. 3; and J. Woodward, Industrial Organization (London: Oxford University Press, 1965).

4. For an interesting discussion of the relationship of novel experience to emerging values, see J. G. March, "The Technology of Foolishness" in The American College President (New York: McGraw-Hill, 1973).

5. See J. K. Galbraith, The New Industrial State (New York: Houghton Mifflin, 1967) for the more developed argument on this point.

6. For a sensible review of the Technology Assessment experience, see A. H. Teich, Ed., Technology and Man's Future (New York: St. Martin's Press, 1972), Part 4. Also compare L. Winner, "On Criticizing Technology," Public Policy 20:1 (Winter 1972), pp. 35-59.

7. This distinction is advanced and discussed in S. Zwerling, Mass Transit and the Politics of Technology: A Study of BART and the San Francisco Bay Area (New York: Praeger, 1974), Ch. 1.

8. See J. Carroll, "Participatory Technology," Science 171 (Feb., 19, 1971), pp.647-653.

9. T. La Porte and D. Metlay, "Technology Observed: Attitudes of a Wary Public," Science (forthcoming, 1974). This article reports the findings of a public opinion survey documenting the degree to which such views prevail in California at the present time.

10. This issue, p.

11. Recently, several programs attempting to stimulate research and teaching directly relating technology to humane concerns have been undertaken. These are the "Technology Studies Program" at MIT and the "Values, Technology, and Society Program" at Stanford University. These join other such programs at Harvard, Cornell, George Washington University, and Georgia Technical University. Informal programs in other institutions which deal a bit less globally with science and society are also much in evidence.

12. La Porte and Metlay, op. cit.