Goals for Technology

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Abstract—If modern technology is to impact successfully on a significant social problem, the quantitative model must lead to a finite set of alternatives, each clearly referenced to its social, economic, and political constraints. From such alternatives, priorities must be established by the political process—it is at this step that the major current impediment to progress occurs. The engineering community carries the responsibility of elucidating the specific decisions which the public must make.

THE SCIENCE advisory system of the Federal Government involves thousands of engineers and scientists attempting to impact the system in a variety of ways—from peer reviewing of proposals to service on standing committees and ad hoc commissions and from personal contacts with members of the legislative branch to overt attempts to influence public opinion. A primary objective of this complex advisory mechanism is to establish specific national goals which represent realizations of the positive contributions technology can make to the improvement of the quality of life in this country.

In recent years, there have been a number of attempts to evaluate this advisory mechanism. Articles in *Science*, reports by Nader's organization, studies by elements of the system (the President's Science Advisory Committee and the Academies), and the growing body of literature on science-government interaction have cited a number of successes (for example, in biomedical research or environmental activity) and certain marked failures (most notably, in the current public attitudes toward technology, but also in such areas as our inability to reduce the annual automobile fatality rate, to curb the drug epidemic, and to ameliorate the serious urban problems).

Indeed, if one looks at the variety of national programs of the past decade which have been developed to attack major social problems, one is tempted to draw the conclusion that the only positive result is the demonstration that each of these will not work. In the area of education, for example: we seem no nearer to a resolution of de facto segregation problems; educational television has been rejected in formal education as a means to obtain improved system performance within cost constraints; computer assisted instruction is considered still a decade or more off by a company which has led in the investment of dollars and creative manpower; the Head Start program is widely criticized; and the Department of Health Education and Welfare has quietly dropped the ES '70's program and less quietly proclaimed performance contracting a failure. One has the impression that every three weeks the *New York Times* announces in a front-page story the fantastic success of a new method for teaching reading, with another lead article faithfully following a week later to announce that test results were manipulated in that particular program.

We seem to be left with only a few new and untested programs: day care centers for pre-schoolers and open universities for post-schoolers. With such exceptions, we are in a state of idea bankruptcy, not only in education, but also with respect to most social problem areas. The paucity of exciting novel approaches coincides with the national recognition that these problems are not as trivial as the technological challenges of developing a new weapon system or placing a man on the moon.

We could go on to chronicle the many confluent forces which lead to the current national attitude toward technology which threatens to force legislation limiting, directly or indirectly, the development of that new technology which is so essential if we are to ameliorate these problems. This is the same national attitude which results in a one-year drop in freshman engineering enrollment from 71 000 to 58 000, and which marshalls public opposition to new technology without any willingness to understand the alternatives.

All of us in technology, however, are far too aware of the difficulties and hostilities we face. It is precisely at such a time that we must forge new, creative, and positive programs. The very fact of the wide perception of the failure of past efforts is, in one sense, the greatest cause for optimism about the future. Not only will any small success represent a refreshing change, but after several years of naive optimism, we now recognize the enormity of the problems, we understand the necessity to make progress by small steps, and we appreciate the complex interaction of social, political, and economic factors with technology. We have laid the groundwork for major technological contributions to education, health, environmental control, transportation, housing, and the like. We are emerging from the difficult conversion from the military-space economy to the civilian economy.

The Basis of a Program

A specific program designed to apply technology to improve the quality of life by effecting change in any particular aspect of that life (education, transportation, etc.) must be based upon an adequate quantitative model of the problem area. If we are discussing a specific service function, the model must encompass not only the costs of the service, but also definitive measures of the quality—or the ways in which there is a deficiency.

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This quantitative model, coupled with an understanding of the modern technology as well as the existing social and political constraints, allows logical decisions on the details of the program. Typically, a long list of possibilities is generated as possible avenues of attack. Social scientific information is then required before priorities can be established within this list—information not only on the impact on all aspects of the social system, but also on human attitudes toward change. When priorities are established, the program then entails technological development paralleled by educational and social programs preparing for the innovation.

In order to illustrate these general ideas, we turn to a particular example: health care. An intensive series of national reports dating well back into the Johnson Administration has documented the relatively poor health status of Americans compared to people in the other advanced nations of the world. (Admittedly, such quantification has to be interpreted with care, since there really are no measures of the average quality of health; instead mortality and serious-disease rates are used.) Furthermore, the many national studies both within and without the Government seem to agree on a number of causes—several ways in which the U.S. health services system is not meeting desired performance levels in spite of the high and rapidly rising cost of health care in this country.

The interesting feature of this list of causes is that in many cases technology can make a definite contribution if the means is found to implement a technology-development program by providing the necessary federal impetus, aggregating a market enough to make the field attractive to industry, and establishing appropriate guidelines and standards.

Even a cursory glance at the causes affirms this potential rule for technology.

1) Senior Citizens: Here the sorry state of nursing homes has been emphasized by President Nixon during his Nashua, N.H., trip and in "popular" terms in the book *Where They Go to Die*, as well as in a series of television specials and articles in the press. The lack of technological development is apparent to any visitor to such homes, where there is essentially nothing to improve the mobility of the physically handicapped, to assist individuals who are unable to care for themselves, or to utilize computer video terminals to provide entertainment. Merely a typewriter designed especially for users who are unable to direct their fingers to a small area would be a significant aid, as Myron Tribus' Dartmouth College students showed in their work with spastic children, and some of these patients could be given a strong purpose by using technology to allow them to prepare materials for blind people. As a final example, there seems little justification for a cost of $1000 for a device to hoist a human being one flight of stairs in his home a few times a day.

2) Middle-Aged: One of the principal reasons for the poor U.S. life expectancy is the relatively high mortality rate of citizens of 25–45. While the causes are not completely clear, certainly hypertension and alcoholism are significant factors. Even more surprising is the high rate of physical disability, with the number of handicapped growing markedly faster than the output of rehabilitation programs. In spite of the publicity associated with the "Boston arm" and elaborate reading machines for the blind, the percentage of physically handicapped who benefit significantly from modern technology is exceedingly small.

With less than 20 percent of the blind reading braille, the need for a national program to capitalize on the low-cost audio cassettes is apparent. Laser canes as mobility aids have been heralded, but the vast majority of the blind experience great difficulty in moving around urban areas. Indeed, until very recently our industrial process did not even make available a folding cane—certainly not particularly high technology.

3) Young Adults: The 15-percent drop since 1900 in the ratio of females to males in this country has received wide publicity because of the implications for women's liberation and the relationship to the optimum marriage age for males and females. One of the important causes of the drop is the death rate among young male adults: deaths resulting from automobile accidents, homicide, suicide, and drug addiction.

Technology can play a significant role in mitigating this situation. In the drug-epidemic problem, for example, system analysis is desperately needed to determine at which points intrusion into the manufacture, distribution, and use network is likely to have a meaningful effect. For instance, the administration has publicized the agreements with Turkey to limit the poppy crop grown there, and on Long Island restaurants are boycotting French wines until France takes strong action to close the Marseilles manufacturing plants. Serious proposals have been made to use satellite observation to monitor the location of poppy growth throughout the world.

Yet none of these measures really seems significant in terms of the U.S. problem (although perhaps they can be justified on world-wide humanitarian grounds). With drug prices in the U.S. markedly higher than elsewhere in the world, this country represents the prime market. It appears that more than 95 percent of the world's poppy crop would have to be eradicated before we could anticipate a major change in the supply in this country.

In the problem of automobile safety, technology can play several immediate roles beyond the obvious improvement of vehicles and highways. The air bag, now dictated for installation in all cars by 1975, requires major technological development, as emphasized in last month's RECAT report by the Office of Science and Technology.

As the President's 1972 State of the Union message and the March 16 special message on science and technology both emphasized, a major effort is needed in the development of emergency medical care systems and devices to reduce the third of the 55 000 annual auto fatalities which are attributed to improper emergency care. The 88-percent expansion in Federal funding proposed for fiscal year '73 for new demonstration projects arises to "pull together the technologies into a system which effectively links communication, transportation of victims, ambulance equipment and service, trained manpower, and emergency room hospital service."

Breadth of a Program

The three aspects just mentioned represent, of course, only a very small part of the model for the present U.S. health care system—the model which shows as vividly the many specific points at which existing technology could be used to modify the overall quality of health care. We have not discussed at all the health problems of children, the soaring costs of care for the critically ill, or the most pressing problem of the more than one-third of our population which is effectively separated from the health care system except in situations of dire emergency. (In this last direction lie perhaps the major challenge and opportunity for instrumentation technology, and one of many chances to demonstrate that technology can indeed enhance individuality.)

From such a model (developed naturally in very much more detail than is possible in these brief notes), we can formulate a lengthy list of alternatives—specific governmental or national programs which effect a positive change in the health status of this country within the existing social, political, and economic constraints. Such a list would certainly include, for example, the following:

a) the design of an array of ambulances and emergency vehicles similar to that now in existence in the Soviet Union and ranging from general purpose to highly specialized;
b) the development of low-cost special-purpose minicomputers for hospital information systems;
c) the realization of a greatly expanded nationwide network of artificial-kidney centers to treat the 30 000 patients annually who are now unable to obtain help;
d) research directed toward malnutrition tests which can be administered early and at low cost to large numbers of people, particularly expectant mothers, where nutritional deficiencies seem to adversely affect the child.

Just these four possibilities point out the wide range of technological difficulties which can be anticipated for the complete list of alternatives. The programs a) and b) are straightforward from a technical standpoint—they require no new technology. Indeed, a) merely awaits some assurance of a suitable market. Program b) requires at least a modest study of the true needs of this aspect of the health care system, or perhaps even more, an agreement among hospital administrators and managers.

Item c) begins to introduce technological difficulties, or at least uncertainties, because of on-going research directed toward cost reduction, simplification, and portability of artificial kidney machines. Finally, the nutritional-test program demands a significant research effort and hence involves more uncertainty as to success.

In each of the hundred or so possible programs which can be listed for improving health care by technology, the description of the program must also include the model for the social and economic constraints within which the new technology must operate. For example, the ambulance-redesign effort (studied recently by both HEW and the National Academy of Engineering) is severely limited by the confusing multiplicity of responsibilities for ambulance operation in the typical city, the stringent financial constraints under which both municipal and entrepreneurial systems operate, the inadequate training programs for ambulance personnel, and a disarray of Local and State statutes governing operation. (The proposed Federal program mentioned earlier will attempt to find, as pilot projects, a small number of localities where this confusion is minimal, in the hope of inducing other cities and local governments to take positive steps to create the legal and social setting amenable to the introduction of modern technology).

Limitations of Technology

Thus we are now at the point where a list of alternatives has been generated, each complete with the social, political, and economic portions of the model and the program plan. Indeed, each can be evaluated on a quantitative basis if we wish to strengthen the argument by demonstrating that a proposed program will yield an equivalent dollar benefit greater than the cost. (Reading various cost/benefit analyses prepared to substantiate proposals, one rapidly gains the impression that the nation could easily utilize its entire tax revenue in new programs which would reap benefits far exceeding costs.)

The actual implementation of any subset of these programs requires a decision on priorities. It is at this point that the political process rightfully assumes the decision-making responsibility. Unfortunately, the political process is often not assisted very effectively by the scientific community. Anyone who has sat on biomedical advisory committees with a variety of physicians is acutely aware of the inability of the medical experts to agree on priorities. Quite naturally, each tends to feel that an additional $100 million of federal funding for health should be devoted largely to his own field of specialization. Every administrator of an existing program is acutely aware of his own funding limitations and argues for expansion of his program in preference to initiation of a novel effort. The politicians have to be sensitive to public concerns and have to emphasize programs which involve the direct flow of money to critical communities or which have a high degree of visibility (such as the artificial heart program or the cure-for-cancer undertaking). Finally, hearings before Congressional committees tend to encompass extreme viewpoints rather than studied evaluations by relatively disinterested experts.

In the midst of all these divergent forces, establishing priorities in a quasi-logical fashion requires exceptional leadership and an exceedingly strong science advisory mechanism—a mechanism which does not hesitate to enter the political arena in order to win support for desirable programs. The professional or scientific society which insists on maintaining assiduously its detachment from the political scene (often under the excuse of retaining its favored status with the Internal Revenue Service) abdicates completely its responsibility to represent its members in placing before the public an accurate picture of the technological features of major issues and to ensure appropriate scientific input to the establishment of national priorities.

Concluding Comment

Most of today's serious social problems can only be ameliorated by the intelligent use of technology. Technology cannot change the urban or social environment and human behavior: it cannot solve major social problems such as unequal education or health care; it cannot solve the problems of increasing productivity in the service sector (which now employs the majority of our workers) and at the same time decreasing unemployment; it cannot yield an appropriate international trade balance regardless of diplomatic and international economic developments.

But in each of these aspects, the human and social use of technology can lead to marked improvements in our quality of life. The technology exists. The needs are widely recognized. We are primarily stymied by our inability to develop workable procedures to establish national priorities at a time when so many competitive forces are acting on the political decision-makers that it is increasingly difficult to focus efforts or resources above critical size on any specific program. Into this gap, the technology profession must move with the individual engineer, the professional society, the special advisory and evaluative committees, and the major national resources such as the National Bureau of Standards and the National Laboratories.

Toward a Framework for National Goals and Policy Research: Notes on Social Indicators

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Abstract—Quantitative information and factual indicators are essential for informed decision-making, and science and technology policy-making is no exception. However, there are no social indicators as there are economic indicators. Direct measures which relate to technological accomplishments are almost impossible to obtain. Analogies and anecdotes are the arguments used for programs proposed in problem areas rather than specific measures or specific indicators which permit the evaluation of the effectiveness of the program.

In addition to the lack of quantitative data, there are economic and institutional practices and regulations on an international, or state and local level that often act as powerful nontechnical barriers to technological enhancement and change. These include state highway regulations, state building codes, tax rates and structures, the patent system, restrictive application of anti-trust and trade regulation, absence of and inadequacy of nonperformance based standards, and subsidies and tariffs.

The methods of scientific investigation and the social engineering called systems analysis which have been primarily successful in the solution of military and space problems have important roles to play in this area. They can provide the framework for the determination of the particular types of qualitative information needed to measure the nation's social health.

Introduction

QUANTITATIVE information and factual indicators, in general, are obviously essential for informed decision-making, and science and technology policy-making is no exception. We are by now so accustomed to seeing and using economic indicators, such as gross national product, price indices, and national income accounts, that economic policies would hardly be considered without reference to a wide variety of these indicators. Social policies and policies related to science and technology, in comparison, do not have similar indicators. Although it may appear as though comprehensive economic indicators have always been available on a routine basis, they actually were developed in the 'thirties, and then were not developed overnight. There is a long history of research and development by economists and econometricians because progress required theoretical developments and was not just a matter of collecting data. It appears, therefore, that there is a long way to go before quantitative support for science and technology policies can attain the sophistication and scope available in the area of economics. No attempt will be made here to lay out the necessary theories for science and technology indicators. What we shall do first is to discuss the need for quantitative information.

Quantitative information for rational decision-making is essential because it enters into nearly all aspects of the process of arriving at good choices. One type of quantitative information can serve to identify problem areas. The greater the detail in the information, the sharper can be the focus in terms of providing an understanding of the problem and the nature of the action that might be needed. For example,

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