TECHNOLOGY ASSESSMENT—WHAT SHOULD IT BE?

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I. INTRODUCTION

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That technology can drastically alter the nature of society is not news. Much of our most important social and economic history is a chronicle of the adjustments which nations and peoples have made to new technology. Today, awareness of the impact of technology on the environment is coupled with a strong and widely-held determination to reap the benefits of technological advance while preserving the environment.

Destruction of desirable environmental qualities is the archtype of second-order effects--the unwanted and unlooked-for by-products of some program or activity undertaken to produce other desirable results. It has been striking that in the adoption of new technologies, the unlooked-for consequences have sometimes been as important as those specifically sought.

The new view is that it is not really necessary for society to be the unwitting foil for new technologies--provided that society can develop the requisite means for analysis and direction of technological change. The classic pattern, documented in the history of the industrial revolution and elsewhere, is that entrepreneurs had enormous freedom to invent and

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adopt new technology where they found it profitable to do so.[1] Today, through technology assessment, means are being sought to predict, evaluate and direct the path of technological change in such a way as to preserve the public interest. Presently mechanisms for these purposes are anemic but they are not entirely lacking. This new emphasis is in an old tradition, broadened to meet modern needs. There were often occasions in the past where untoward effects of technology could be anticipated by persons in a position to exercise some control. A classic illustration is the doctrine of riparian rights which became important with the emergence of water power as a basis for industry, particularly in New England. The effect of an upstream dam on downstream users of water was direct, obvious and easily anticipated. Here, at least, legal sanctions did protect the downstream users from the impact of a new technology (the upstream dam and industrial plant run by water wheels) through the normal processes of law. But the downstream users were a small portion of those who were affected by the development of water power-based industry. The concept of riparian rights did nothing about poor working conditions and squalid living conditions. In short, control over second-order consequences, which is the heart of the technology assessment idea, was partial but far from complete.

Throughout history new technology has given rise to problems comparable to those which concern us today. There is reason to believe that the unexpected consequences of today's scientific research may be even more significant and occasionally more devastating than that of the 18th and 19th centuries. Because the results of science are always new, frequently the knowledge necessary for anticipating effects is not available.

The National Environmental Policy Act of 1969 is the latest manifestation of the philosophy that it is the responsibility of governmental agencies to supply solid information, based on sound analyses of certain second-order impacts of its programs, and of the activities of sectors of the economy to which it is related. The Act imposes new obligations on every program and agency to perform an assessment of new technologies which it intends to implement as part of its process of planning and implementation. Legally, agencies cannot proceed with their programs until satisfactory studies have been performed. And these studies will require a level of effort and data which considerably exceeds that which is now available.

The Scope of Technology Assessment

Technology assessment, in its present state, is essentially a rallying cry for an extremely mixed group who are convinced of its need and potential. Technology assessment is apparently on its way to becoming a cross-disciplinary, problem-oriented and generalist type of expertise. The process of arriving at a commonly agreed-upon definition is tantamount to a process of agreeing on scope, method, and the future development of technology assessment.

It is important that technology assessment not be restricted to evaluating new results of science and engineering. Because the word "technology" is often thought of narrowly, there is a tendency to conceive of technology simply as a synonym for science, scientific research, development and engineering. Those who use the word "technology" in this way tend to think of technology assessment as wholly concerned with the impact of science and engineering and the implementation of new techniques recently emerging from research and development. But technology assessment should be concerned with evaluating the full range of techniques that are relevant to a particular decision or change. Changes in social and political institutions should not be excluded. This is a broader definition than is usually advanced, and is based on the thought that technology is essentially the technique by which society accomplishes its goals. Thus technology assessment is concerned with the total direct and indirect consequences of the choice of technique, and particularly of changes in technique. Narrower definitions are generally colored by a strong reaction to the role that science and engineering play in changing society. They tend to focus on what their advocates consider to be the most important or strategic areas for assessment of change in technique.

Actually, the popular identification of technology with science, development and engineering is not a universal usage. Technology properly means the technique by which something is done rather than the process of introducing new technological possiblities or changing technique. To say that the technology of an advanced industrial country differs from the technology of an emerging country is merely to say that the techniques by which people are housed, fed, clothed, transported, etc. differ. It is because this meaning is not widely adopted that there is so much confusion as to the meaning of technology assessment; the confusion is over the word "technology" rather than assessment.

One of the more complete statements of the meaning and impact of technology was made by Jacques Ellul. In the language of his translator,

> "The term <u>technique</u>, as I use it, does not mean machines, technology, or this or that procedure for attaining an end. In our technological society, <u>technique</u> is the totality of methods rationally arrived at and having absolute efficiency (for a given stage of development) in every field of human activity."[2]

Applied psychology and sociology are techniques of sport. If we recognize that the method each person employs to attain a result is, in fact, his particular technique, the problem of means is raised. In fact, technique is nothing more than means and the ensemble of means. It would be more consistent with Ellul's usage to speak of technique assessment, rather than technology assessment. What he means by "la technique" is at least as broad as the usual meaning of technology.

Given popular usage, the word technology seems to be necessary, since--at least in America--"technique" conveys too narrow a meaning. However, the word technology suggests a preoccupation with changes in technique adopted because science and engineering have made new techniques available; the strategic idea behind this orientation is that these are the changes in technique that it is most important to study. But it would be difficult to argue that changes in social institutions are, today, any less important. These need the same assessment as do the results of research and development. Further the methods and expertise are much the same for changes from any source, and all types of societal change are very much interwoven. The processes of research and engineering are often as likely to be initiated in response to social change as the other way around (e.g. home appliances by the disappearance of a domestic servant class.) While focusing on the impact of R&D may be sound strategy, it is a clarification to distinguish between assessing the impact of society's choice of technique and the problem of selecting priorities for groups engaged in technology.

It is change itself rather than the cause of changes which creates problems for society. What should concern society is not broadened awareness of alternatives, but the process by which alternatives are selected. While science and engineering, by making available superior techniques, accelerate change, society undergoes changes even in the absence of new techniques. Political, social and economic forces result in switches from one set of techniques to another, frequently with profound consequences; these changes too need assessment.

It is transparently clear that the important second-order consequences of technology in the broad sense are often social and economic impacts. While much of technology assessment is hard science, the orientation for such analysis and the assessment of consequences of physical effects of technology are the province of the social sciences.

Technology Assessment as Analysis

Technology assessment is analysis, and its methods are essentially the analytical methods of natural sciences, social sciences, jurisprudence, etc.

While technology assessment is frequently the analysis of actual or proposed change, it can also be analysis of a lack of change where change is possible. It reflects a new pragmatism in which second-order consequences that an earlier generation would tend to ignore are seen to be of considerable importance. It is unique in that it not merely focuses on identified second-order consequences but displays an uneasy awareness that unidentified consequences may also be important. It displays a similarly uneasy awareness of the enormously diffuse and interwoven patterns of effects--known and unknown--that may result from the choice of technology. The current usage of the word "environment" to include the whole array of effects on plants, animals, the atmosphere and waters, and all aspects of human existence is a useful catch-word. In this context, technology assessment can be said to be concerned primarily with environmental impacts of technology, while it would be misleading if "environment" were narrowly defined.

The pragmatism behind the technology assessment idea reflects the belief that society has the means for implementing its deliberate choice of technology, so that assessment is not merely an idle exercise. Inevitably those concerned with technology assessment focus strongly on the processes of government by which society implements its choices. In practice, this often amounts to the planning of governmental programs, the evaluation of proposed new programs and of on-going programs. Much of the strategy of technology assessment groups has therefore focused on providing the Congress, the Executive Office of the President, and their equivalents in state and local governments with the means to put first- and second-order consequences in perspective.

The justification for technology assessment is that it brings within the decision framework the consequences of the use and choice of techniques whose impacts tend to be overlooked by organizations whose interests are focused elsewhere. First-order consequences, the objective of the agency and its mission, will generally have been studied, evaluated and selected primarily for their effectiveness in accomplishing the assigned missions. Second-order consequences can assist in program justification, or may be the basis for objections to programs. For example, reduction in welfare costs would be a definite consideration in a manpower training program, although conceptually it would be an indirect, second-order consequence.

Although the methods of technology assessment are those of known and established areas of analytical expertise, it seeks to apply them in an integrated manner to extremely unpliable material. Its special difficulties are the result of its subject area. It is difficult to be succinct as to the processes of analysis. Every discipline has its own methods, the combined result of its intellectual traditions, the skills in which its members are trained, the characteristics of its subject area, and of the information that it works with. Particularly among the disciplines that have been infused by the methods of science, there are strong similarities in methodology. The extent to which a particular discipline uses these methods is evolutionary, and only in recent decades has there been much application of the methods of science in disciplines strongly oriented toward other analytical traditions, such as history, law, etc. Those disciplines which have a methodology for prediction or analysis of the hypothetical are especially adapted to technology assessment.

However, a few points stand out with respect to the structure and elements of a technology assessment exercise. First, technology assessment is predictive, since it is directed at the consequences of the choice of method at a time when the events lie in the future, or are still hypothetical. Second, technology assessment focuses on the obscure--the second-order effects of changes in methods that result from little understood or wholly unsuspected linkages between cause and effect.

Third, technology assessment is typically undertaken at a time when the principal direct or first-order effects of programs are themselves imperfectly understood. It is reasonable to ask, when the planned sought-for results of programs so often fail to materialize as expected, if there is much hope of predictive success with respect to unexpected effects. Early in the development of programs the specific policy actions or choice of methods is an open question subject to a wide range of choice, and highly significant differences in second- and higher-order consequences may be involved.

Fourth, technology assessment is generally undertaken without clear statements of program objectives or criteria for evaluation. There are frequently no well-defined policies with respect to many of the second-order consequences on which a technology assessment might legitimately focus. Ambiguity of criteria and objectives with respect to second-order effects, or a reasonable set of value judgments, is very common.

Fifth, one of the principal problems of technology assessment is that analysis may necessarily be formulated in ways that would require non-existent information as to causal relationships. Often relationships that have never been thought important have never been studied at all--and even relationships which have been studied intensively are often imperfectly understood.

Sixth, and related to the previous point, even where relationships are known, the process of calibrating them frequently requires non-existent data. Some of the data will be social indicators, and for them it will often be necessary first to determine how reasonably accurate, meaningful social indicators can be devised. Precise definitions, the starting point for meaningful data collection, are often lacking. Characteristically, the statistics-gathering establishments have not sought data that have not been considered important, and they have not caught up with the new demands created by the interest in technology assessment.

Technology assessment has been, up to now, generally undertaken with very limited resources and under time pressure which makes it difficult to grapple adequately with the analytical problem.

None of these attributes are unique to technology. In total, they amount to precisely the array of obstacles that generally leads an analyst whose training lies in some established discipline to move on to some other problem. Recently, Paul Samuelson referred to a maxim of his fellow Nobel prize winner, biologist Peter Medawar, that science must deal with that which can be managed, eschewing the intractable.[3] By these terms of reference, technology assessment is not a subject for scientific effort, and it is hardly well-chosen by the discipline-oriented scientist seeking solid professional accomplishment by applying the accepted methods of his discipline. Technology assessment is precisely the kind of problem which graduate students sometimes suggest for their Ph.D. dissertations, and which responsible faculties steer them away from.

The justification for technology assessment is not its tractability but the importance of providing the body politic with means for understanding the whole implications of changes of method. The body politic is not obliged to ask simple questions or questions for which established disciplines operate efficiently.

If the members of every discipline decline to operate on problems for which their skills are not adapted, there will remain a significant array of modern-world problems which no discipline will accept. Among them will be many of the problems with which technology assessment is concerned. Technology assessment is problem oriented in the sense that it seeks answers to problems arising from change of method according to the importance to society without regard to the state of the analytical machinery. Inevitably, technology assessment focuses on some intractable problem areas--and indeed, the tendency of the scientists to seek out problems tractable to their disciplines means that the crucial unanswered questions on which technology assessment focuses tend to be cross-disciplinary and intractable.

All disciplines are problem oriented in their own terms and it would be a gross misrepresentation to suggest that the sciences are not problem oriented either in their historical development or present-day practice. From the public policy standpoint the difficulty lies in the selectivity criteria which scientists typically apply to problem selection. A scientist cannot build a reputation by dealing with tractable but unimportant problems. Reputation building is based on identifying important problems where success is within reach. Clearly, many such problems are important. The science policy machinery of the U.S. is especially efficient in calling the attention of the scientific community to important problem areas that lie within disciplinary areas. Conventions, committees, panels selectively making federal funds available are part of this mechanism.

Consider the relevance of the above observations to introductory remarks on the technology of teaching aids, by the National Academy of Engineering's Committee on Public Policy:

> ...a complete assessment of the technology of teaching aids would be concerned with the consequences of the interaction of technology with all educational institutions and methods.
>
> An assessment of such scope was considered to be too broad for this study. Since the principal backgrounds of

> the Task Force members were in the field of higher education, it was decided to limit the assessment effort to the impacts of technology on the institutions of higher education in the United States.[4]

As this effort purported to be an experimental technology assessment, the quotation draws attention to the difficulties of performing technology assessments using persons drawn from various disciplines, with habits of thought, roots and perhaps future aspirations related to those disciplines.

In short, technology assessment as an analytical effort is the superimposition on the old of a new focus and a new orientation. It would be a mistake to consider it merely a new name for old analytical procedures, but there will be little in it that is wholly unfamiliar to persons trained in one kind or another of discipline-bound analysis.

Nonetheless, the adjustments which must be made in problem selection, orientation, and cross-disciplinary flows of analytical inputs and data would appear enough to make it likely that a wholly new disciplinary tradition will emerge as the volume of technology assessment activity increases. It is likely, ultimately, to emerge as a discipline in its own right. It is clear from the history of science that new methodologies can emerge from what previously had been intractable problems, that increasing the level of effort accelerates the development of the requisite methodology, even if the process is slow and uncertain.

II. STATUS OF THE ELEMENTS OF TECHNOLOGY ASSESSMENT

Prediction

Because technology assessment is future-oriented analysis, any analytical method with the capability of relating past and present conditions to the future may be useful. Prediction is, of course, an ancient art and, especially in the soft sciences, heuristic methods are traditional and sometimes all that are available. But they need not be unsystematic, as has been shown forcefully by the emergence of procedures such as RAND's Delphi.[5]

Increasingly, the forecasting of technological change has made use of analytical methods and results--though it would be going too far to call technological forecasting a wholly analytical process. The variety of intuition-analytical mixes which prevails is considerable.[6] Whatever the area, the most credible predictive methods are based on structural models which relate time-lagged dependent variables to independent variables for which data can be obtained. Demography and weather forecasting are examples of predictive sciences on a solid theoretical foundation.

While there is often widespread faith in the meaningfulness of predictions, their validity is rarely examined with any rigor. The faith may be largely misplaced. Of all disciplines, economics has been more explicitly concerned with prediction than most. Previews of economic forecasts of Gross National Product, mostly by trained economists using well-developed theories and structural models, indicate that success of the more elaborate formulations is quite limited compared with such procedures as extrapolations of trends.[7]

<u>The Obscurity of Consequences</u>

The obscurity of the linkages between sought-after results of choice of method and second-order consequences results in part from lack of adequate structural models, and in turn is attributable to the general disinclination of scholars to create models until they serve some purpose. Not until concern for second-order consequences becomes general will motivations to create satisfactory models become strong in a pragmatic society.

Unfortunately, as models are expanded to deal explicitly with more and more second-order consequences, they become larger, more complex, and unless deliberately limited, they would ultimately encompass every aspect of every element of society.

Studies of second-order effects are almost inevitably system-like in characteristics. Where the focus of analysis broadens, the system-like structure of problem areas--and therefore of analytical methods--tends to affect the nature of analysis and the management of analysis. The high similarity of analytical needs where system-like problems are of interest has been widely noted, and has generated a relatively new body of literature--e.g. general systems theory.

But the art of model-building traditionally is one of simplification, of hewing to the line of fundamental relationships, and specifically setting aside second-order effects. Especially in the social sciences, the successful model generally relates only the principal part of the variations in dependent variables and leaves exploration of discrepancies between model-predicted and actual values of dependent variables to informed interpretation. Thus, the obscurity of second-order consequences tends to be built into existing methodology. While the problems of obscurity are serious, it is reasonable to believe that they can be reduced by differently orienting model-building.

Identifying consequences in explicit physical terms will rarely serve the purposes of technology assessment. The final link, between the physical and the public welfare implications must also be made. Welfare economics provides the most highly developed methodology which seeks to relate consequences in physical terms to "utility" or welfare, and this methodology is important in technology assessment both because economic consequences are important and because it is a paradigm for other disciplines. However, welfare economics is not the only approach to analysis of consequences, and the analysis of consequences in a framework narrowly oriented to the methodology of welfare economics is neither necessary nor desirable.[8]

Uncertainty as to the Policies to be Analyzed

For a technology assessment to proceed systematically, the analysis to serve the purposes of technology assessment must be of alternative policies that have been spelled out with reasonable explicitness. If such information is not available in the early stages of policy, the only practical solution may be creativity on the part of a technology assessment group--the articulation of a spectrum of policies considered to approximate what is likely to be considered seriously by the policy makers. Such exercises require a full appreciation of organizational goals, methods, and environment, including an intimate knowledge of the organization to which the policies pertain.

To retain the objectivity necessary for valid analysis, a technology assessment group must develop the prototype policies needed for analysis without acquiring an emotional or intellectual commitment to its own creations. This is so contrary to human nature that some separation of function may be essential. There is also, potentially, another dilemma. The effort of defining and selecting policies is, for any agency, a major effort. The existence of a useful expertise in a technology assessment group may result in participation in agency policy formulation in ways that may bias the technology assessment function.

Lack of Clear Statements of Objectives or Criteria

In many organizations statements of objectives are considered to be window dressing, without direct operational or planning significance. Yet the dominant theory of planning insists on starting with a statement of objectives framed so that it is possible to relate them explicitly to program content.

Statements of objectives have an operational meaning only when they reflect the guiding principles of organizational leadership and it is often difficult to persuade leaders to expose their own value judgments, and to generate statements of objectives to which they feel any deep-felt sense of commitment. Even where they try, the statements often have deficiencies--objectives which are better left unsaid are omitted. Agency heads frequently cannot, in short simple exercises, articulate sets of objectives in terms of which future agency actions are comprehensible. Much of the art of political analysis amounts to deducing from actions what the objectives of political leaders are, in contrast to what they are claimed to be. Deliberate deception is not necessarily involved--leaders as well as others simply do not know their own mind until put to the test. Planning can be disoriented by incomplete or inapplicable statements of objectives, and technology assessment is likely to suffer in the same way.

Technology assessment would benefit from the emergence of a theory of planning which would direct efficient goal-seeking behavior without a statement of objectives. Lacking this, a technology assessment group has no alternative but to assume agency objectives on the best available evidence.

Beyond this, the broad social orientation of technology assessment requires statements of objectives for society as a whole. It means assumptions as to the value judgments of society, and somehow integrating a broad range of differing and perhaps conflicting objectives and value judgments.

Unknown Functional Relationships

The long run strategy for technology assessment must be to identify important unknown functional relationships and persuade government to fund, and scholars to perform, studies that will define and then refine knowledge of them. This suggests on the one hand a broadening and deepening of the processes of much scientific research. It further suggests that one of the outputs of technology assessment must be explicit guidance to scholarly communities of what studies can ultimately contribute to the technology assessment process.

Before this process can start, however, the existence of functional relationships must be at least suspected by persons or groups with the ability to carry their ideas forward. There is, to be sure, an enormous need for making precise partially known relationships. Perhaps there needs to be as much concern over those that have not reached the level of awareness; certainly, if technology assessment is ultimately to meet society's needs, it must include a search for obscure relationships. Often analysis is manageable once the question is posed, but who is to pose the question?

Non-Existent Data

As with functional relationships, technology assessment must identify needed data and persuade funders and scholars of its importance; this is also a long-run approach. The kinds of data needed will often differ materially from that now collected. Some kinds will involve substantial conceptual thinking. As already noted, social indicators are often relevant to the data problems of technology assessment, and indeed some problems are merely the non-availability of appropriate social indicators. An example is an indicator of "quality of life." The various dodges suggested for indicators of such characteristics, including surrogates, will often be helpful.[9] An important consideration is constructing models in terms of available data, where models in these terms can be satisfactory for the purposes of technology assessment.

For reasons of lack of data, the models constructed immediately may be compromises with structural reality. The unease with such compromises--whatever their predictive success--is a strong motivation to create new data series which are appropriate to structurally valid models.

Will technology assessment be stymied by lack of data? Perhaps often so. Yet productive analyses by informed men have often overcome data problems, and indeed the early history of many sciences tells of the emergence of theories with long-standing validity at a time when data were crude or non-existent. It also saw the emergence of many wrong ideas. Technology assessment has the option, where data are not obtainable in the requisite time frame, of performing no analysis or taking the risk.

It seems also to be true that many technology assessments have failed to take advantage of reasonable opportunities to generate new data. Technology assessment groups have generally not been staffed to generate new and scientifically valid data on a quick-reaction basis. Instead, the staffing level of data-gathering groups and governmental agencies allows them only to operate at a snail's pace, and they are burdened with delaying review procedures. When technology assessment becomes a more leisurely process, the delays will be less serious than they are today.

It is by no means clear that data-gathering agencies must operate at the traditional slow pace. For instance, commercially oriented survey organizations (the public opinion polls) collect scientifically valid information on newly arisen public issues in relatively short periods of time. So far, there is no tradition of expedited data gathering to serve the purposes of technology assessment.

III. ESTABLISHING THE EXISTENCE OF SIGNIFICANT SECOND-ORDER RELATIONSHIPS

The Problem

One of the principal strategic problems of technology assessment is discovering some means by which second-order effects can be identified. It is hardly possible to initiate an analysis of an effect which is not suspected. With respect to a proposed program or activity, the organization that has established the program as the preferred means for accomplishing its sought-for goal (the first-order effect) will probably be aware of some second-order effects. It may, indeed, decline to identify these for a technology assessment group if it suspects that the result of the analysis will inhibit it in securing approval for or implementing its primary program, but it is likely to identify some. Others will occur quickly to the technology assessment group or will be called to its attention by interested parties.

However, these means of effect identification are rather hit and miss. What is needed is a systematic approach to identifying the full range of second-order effects. Once this is done, the follow-on program is one of analysis, but it is by no means true that depth analysis is justified for every imagined or suspected effect. Many suggested second-order effects will be spurious, or inconsequential by any criteria. For effective use of analytical resources these must be screened quickly. The process of screening is itself an analytical effort of markedly different character than analysis in depth. In screening analysis, the emphasis is on economy and speed of effort--on the application of pass-reject criteria, from which the passing items move on to analysis in greater depth.

Organization for Screening Analysis

The critical points in these preliminary stages are coverage and efficiency. To obtain completeness of coverage, a technology assessment group responsible for preliminary screening should function as a wide open receptor. It will receive a great deal of debris, but no matter, since the function of screening analysis will be to filter out the debris before much time or effort is spent on it.

At this stage, there must be an active search for ideas. Efforts should be made to stimulate ideas by presentations, raising of issues and problems among types of persons who had not thought about the matter before. The depth of such presentations should be tailored to the character of the persons involved; it can be shallow for those who are not prepared to think more than casually about a problem area, and deeper for those who are better informed.

Every idea or suggestion should be recorded, summarized, categorized and entered into the system, to remain there until disposed of. There will be enormous redundancy in ideas obtained in this way, but with an efficient information processing system, this need not be a problem. A classification system, applied to each separate input, will often identify it as identical to an input previously received, and in these cases there would be no increase in the total number of ideas. As the cumulative number of inputs increased, the frequency with which new ideas were received would decrease, so that the total number of different ideas would tend to level off as a function of the total number of inputs received.

A preliminary screening analysis is needed, conceptually, for every idea--that is for every cell in an idea classification scheme applied to inputs which is not an empty box. The total necessary number of screening analyses therefore tends to approach some upper limit asymptotically.

Efficiency in the screening analysis function is obtained through the multiple use of the analyses themselves. The first time an idea is received and classified according to certain characteristics, the screening analysis would be performed. On receipt of another idea in the same cell, it would not be performed again. Only a portion of cells would contain ideas that would be passed on for analysis in depth.

Undoubtedly many short cuts can be developed that will permit economies of effort in screening analyses. As an example, the Patent Office has, for decades, infuriated a certain type of inventor by refusing to issue patents for perpetual motion machines. Its position is that physical laws make such machines impossible, and that any "inventor" who claims to have reduced a perpetual motion idea to practice cannot, on prima facie evidence, have done so. So far, the Patent Office has not been shown to be wrong, and its policy permits it to reject certain applications very quickly and with minimal analysis. There are always dangers in screening criteria. They must be continually reexamined and rejustified.

Further, many screening analyses will share elements with each other; obviously a routine step in development of a new screening analysis would be to search for useable elements in available analyses.

Revision and updating of screening analyses must be one of the continuing activities of a technology assessment group. The basis for the pass-reject decision should be subject to periodic scrutiny, preferably from new points of view; this process would be abetted by turnover among the persons doing the screening.

The above comments suggest that the historical development of a technology assessment function would be as follows. Initially, a large backlog of ideas would be built up, beyond the capability of a technology assessment group to deal with them quickly. Priority for analysis would be established, and the backlog would gradually be whittled down until a screening analysis was available for every possible idea. As the backlog was reduced, it would be found desirable to redo some of the screening analyses, and the workload would shift from a predominance of initial screening analyses to refinement of elements in the file of screening analyses. It is not likely that the total flow of ideas would decrease very quickly, but an increasing portion of them could be disposed of through quick referral to an existing analysis.

This concept is probably oversimplified in many ways. For example, there are probably cycles in the rate at which inputs will be received. As an agency effectively handles inputs, an increasing level of general public satisfaction with the effectiveness of technology assessment will tend to reduce the flow. Episodes, at irregular intervals, will temporarily increase the flow. However, a popularizationoof old material--which happens periodically--will not increase the needed file of analyses but only the volume of inputs processed by referral to existing analyses. Occasionally something fundamentally new may emerge, followed in due course by an increase in the number of preliminary analyses.

Analysis in Depth

Preliminary screening is merely the initiation of the technology assessment function; there is no real accomplishment until the ideas which pass the screening have been considered in depth. Depth analysis would be analogous to the systems approach, and would include problem identification, creation of a general model of the relevant situation, identification of the needed inputs, definition of subtasks by specifying the relevant inputs and outputs of each, and the nature of the necessary integration, together with an evaluation of the importance, the priority that that agency might give, the appropriate time frame and level of effort. The structure for analysis outlined in Part I and II of this paper suggests how analysis in depth might proceed.

IV. ASSESSMENT AND THE UNCERTAIN CONSEQUENCES OF TECHNOLOGY

The Inherent Uncertainty of Second-Order Consequences

Forecasting miscalculations are common even where techniques are ostensibly well developed, applications straightforward, and the event forecasted easily defined. For example highway engineers routinely forecast traffic volume when widening highways, yet their errors are notorious. The history of business is replete with faulty expectations, and indeed the dispersion of business foresight is held by some economists to be essential to the operation of a free-enterprise economy.[10]

Men hold unreasonable expectations for forecasting. Many approach forecasting as if future events flowed precisely in a cause-and-effect relationship from present conditions. However, many kinds of events are inherently stochastic--just as there is a 50:50 probability of heads or tails. There is no way of predicting any toss of a coin with greater (or less) than a 50% chance of being right.

The inherent limitations in forecasting where processes are stochastic is part of the dilemma of technology assessment. Where outcomes are stochastic the possible outcomes and the probability distribution of the whole array of possible outcomes must both be forecasted. The distribution of outcomes is often conditional on the actions of government, and the task of technology assessment is to establish separate distributions for each alternative policy. Most relationships are a combination of precise determinism and a stochastic element as is so cogently expressed by regression equations with an error term appended. The magnitude of the error term depends jointly on the completeness with which the model specifies the real relationship, and the inherent randomness in the relationship; only the first part can be reduced through more sophisticated modelling--and then only if data are adequate.[11]

Decision Theory and Technology Assessment

It may be that often there is no possible way to know in advance what the adverse second-order consequences of a change in technology will be. However, the basic premise of technology assessment is that an intelligent judgment can be made as to whether or not to implement a new technology. Through the use of decision theory, it is not necessary that the effects be identified precisely, if the spectrum of possible effects can be.[12]

Technology assessment will clearly always operate in an atmosphere of uncertainty. The science of making decisions under conditions of uncertainty has advanced rapidly in the past few decades to the point where some instruction in it is a standard requirement for students of business and management. The content of decision-theoretical models is widely known, and the following simplified illustration serves principally to put the strategy of a decison-theoretical technology assessment methodology in context.

In order to apply decision theory it is necessary to: 1) enumerate and identify the possible courses of action that an agency might take (including no action) and 2) enumerate and identify the possible consequences of each course of action. By cross-classifying the two, a matrix of all possible consequences of all possible courses of action is created.

An additional step is to estimate the value received for each of the cells in the matrix. While this is easy where only a single dimension of the consequences is relevant (e.g. profit in a business firm) it is increasingly difficult where there are many relevant dimensions of each consequence, not reducible to a common denominator; the difficulties are widely understood and are the subject of considerable literature. Consequences can be expressed in physical or "welfare" terms--the latter depending on an ability to relate physical effects to welfare.

A third step is assigning probabilities for each consequence; since the model deals with what has not yet happened, these probabilities must be derived from the best available judgment. The fourth step is to determine the costs associated with each course of action that the agency might take--and each outcome that might flow from it. In public policy applications, not only costs appearing in an agency budget, but external costs including social costs can reasonably be taken into account, and the philosophy of technology assessment suggests that they should be.

Given these data, decision theoretical models provide a framework for selecting among possible programs. There remains the question of the selection of criteria--which has been discussed extensively in the literature. For example, one criteria might be to select that course of action for which the expected net value of the set of consequences that might flow from it is maximized.[13]

Information Requirements for a Decision-Theoretic Approach

Whether or not a decision-making structure or some other approach is used for a technology assessment, the kinds of information, the manner in which information is structured and the considerations involved in focusing analytical effort are essentially the same. The mode of analysis does, to be sure, affect the kind of information needed, but it is a matter of degree and not absolute qualities. In fact, nothing precludes analysis of the information by a number of distinct methodologies, of which decision-theoretic models are only one.

Models from any source are of very little use until their parameters are estimated. One of the telling deficiencies of the usual textbook presentation on decision theory is that it focuses on the manipulation of data on costs, consequences and probabilities on the assumption that they are at hand, ready to be plugged into a decision-theoretical model.

The procedures for estimating parameters are distinctly different than those for model building. The disciplinary boundary between model development and the development of the inputs which make real-life applications of models possible is unfortunately fairly sharp; one of the problems that must be overcome in technology assessment is bridging this gulf, not necessarily by transforming model builders into data generators but by implementing an adequate appropriate coordinating function.

In fact, generating the inputs may be a much more substantial effort. The decision-theoretical model identifies the kinds of information that it is important to develop, the actual development of that information is not part of decision theory; rather it may be engineering, econometrics, sociology, psychology or something else.

The starting point for information needs is identifying the array of consequences and programs. Initially, a matrix might reasonably make a place for every suggested consequence and every suggested program alternative. Given such a matrix, every cell is a distinct analytical exercise relating program characteristics to a system-interconnected string of consequences, and the analysis to back up a single cell in the matrix may by itself be a very large exercise.

It is with respect to the analysis of cells at this point, that the problems discussed in Part II are particularly relevant. The use of a decision-theoretic model does not alter, but merely structures the processes of analyses by defining explicit arrays of assumptions and ground rules.

However the decision-theoretic model does have some unique requirements. Consider the most difficult area--that of the benefits and disbenefits associated with various activities and programs. Their multidimensionality is the heart of the problem; it is necessary that comparisons be made of benefits conferred on different members of society, as well as comparing different kinds of benefits.

It is because of this multidimensionality that a two-dimensional decision theoretical matrix will not serve; clearly there will be analyses for which it will not be appropriate to reduce all consequences to a single numerical value, and where the analysis must be conducted in terms of several dimensions of consequences, as well as several dimensions of program characteristics. The two dimensional model merely illustrates an underlying principle which can guide preliminary technology assessment. Any economist will recognize in this set of concerns the central--and largely unsolved--issues of welfare economics.

Somewhat paradoxically, the best use of the resources of a preliminary screening group suggests minor attention to two classes of cells--those that are clearly very unimportant and those which are clearly very important. With regard to the second, some cells will require intensive analyses which go beyond the resources available to any such assessment group. Where the costs and benefits associated with the cell are clearly of major importance, the problem should be referred quickly to management with the recommendation that it implement a major study. Thus, a preliminary screening group would focus its resources in a middle ground--on those cells where it is not clear that they are neither very important nor inconsequential.

An integral and developed part of decision theory is to calculate the value of information, and through comparing it with the cost to determine the net benefit of acquiring the information. In general, there are some cells in the matrix where the contribution of high accuracy information to decision making is not important. Thus, in marshalling analytical resources, perfunctory analyses will often serve nearly as well as elaborate ones, and analytical capability can thus be concentrated on the cells where the payoff from information is greatest.

V. CONCLUSION

Technology Assessment in Analytical Context

It is clear that technology assessment--even a preliminary technology assessment--means balancing the desirable against the undesirable. The Council of Economic Advisers to the President says "while it might be tempting to say that no one should be allowed to do any polluting, such a ban would require the cessation of virtually all economic activity."[14] It is characteristic of much of the concern over second-order effects that many proponents look only at adverse consequences of programs without balancing these against the desirable results. Clearly, this balance must be struck in every administrative decision, and to do this requires integrating not only information on second-order consequences, but also the desirable consequences which are the primary purpose of the program.

Technology assessment cannot reasonably be considered to be the whole analytical scope of program analysis. There is, therefore, a need to integrate the results of technology assessment with other program analyses. The essential consideration is that the results of technology assessment be supplied in a form that permits integration with other information.

There is a need for consistency of definitions and classification schemes. It is the usual practice in cost-benefit analysis to discount future costs and returns. Official guidelines prescribe the discounting rates. Cross-the-board consistency in program analysis depends on uniformity of the rates so that if technology assessments use discounting, it should use the rates currently in use for related program analyses. In aerospace-type systems analysis, establishing the compatibility of analyses is one of the functions of systems engineering--a coordinating role.

Some part of the notorious difficulty of successful interdisciplinary research results from the incompatibility of data outputs from various disciplines, as they are normally produced. Only in a few instances and for some disciplines have successful bridges been built. For example, certain elements of the behavioral sciences are now fairly well integrated into the work of some economists, though others resist the integration bitterly. In a classic article, Hollis Chenery showed how the results of an engineering analysis, expressed in the format traditional to engineers, could be transformed into the format useful to economists.[15] Dorothy Rice has, in a well-known study, transformed life expectancy data into a form useful in economics and cost benefit analysis.[16] Technology assessment must be interdisciplinary, and the integratability of analysis is crucial. Interdisciplinariness in research does not mean merely a willingness to listen and respect each other. The results of analyses tend to be data, and an interdisciplinary analysis must meld--and not merely report on alternate pages--results from a number of disciplines.

Can Technology Assessment Produce Results?

For technology assessment to be worthwhile, the decisions and follow-on actions of governments and other organizations must somehow be different than they would have been otherwise. It is instructive to examine the impact of planning studies, which are markedly akin to technology assessment--indeed, it is possible to consider that technology assessment amounts to a broadening of the focus of planning.

The frequency with which planning studies have been ignored by decision makers is notorious. Although the quality and content of the studies is sometimes at fault, it would appear that the most common difficulties lie in the relationship between the planning body and the decision makers. Planners often fail to include plans for implementation. Indeed, planners who perceive their role as technicians severely limit their willingness to deal with and make explicit recommendations for implementation.

These same considerations are bound to affect the degree to which technology assessments affect public decision processes, although it is presently difficult to see the technology assessment specialist as a policy-neutral technician. While some--and perhaps considerable--lack of consideration and utilization of technology assessment must be expected, every effort should be made to minimize it, if only to increase through utilization the efficiency of the analytical effort of technology assessment. Efficient use of analytical resources is certainly a worthy objective; everyone would agree that it can be enhanced by the efficient organization and implementation of studies, but unless final reports are to be the end products, applying the criteria of report quality to a planning effort is a suboptimization; a more meaningful criteria is obtained by comparing benefits to society that flow from decisions with the study and without it. In these terms, a mediocre study by professional criteria may actually be superior to glittering gems of analysis, undecipherable to nonprofessionals.

As to the means by which technology assessment can be efficient in these terms, there is room for considerable speculation. I would advance a few propositions:

- technology assessment will have more impact when the analysis is competent.
- it will have more impact when it conforms to the values and philosophies of decision makers.
- it will have more impact if its results are communicated to decision makers before they become committed to specific programs.
- it will be more acceptable when it is relevant to the high-priority decisions which are the immediate responsibility of the decision makers.
- it will have more impact if it does not threaten the power or prestige of the decision makers.
- it will have more impact if it presents alternatives rather than calling for or demanding one rigid course of action.

The last point is particularly debatable, since it runs counter to a highly popular strategy--namely the presentation of a single program as the only possible course of action, around which all available support can be marshalled; presenting alternatives may dissipate support for any action at all, and indeed is a common tactic of opponents of any action. But the function of technology assessment is not advocacy, but to give decision makers a larger and better hand from which they can select their trump cards.

Implementation in the public sector as a political process is often left out of planning. The implementers, as elected officials, are oriented toward widely varied emphases, systems of values, and reflect different balances of community interests. In a typical public decision-making body a large number of points of view are involved, and the resulting decisons are typically a compromise. There is, therefore, rarely a single cohesive set of value judgments, preferences and community interests which can serve as a starting point for the planning process.

Technology assessment is an exercise in value judgment as well as in the development of hard factual information. Second-order consequences may be the hard information part, although the fact that a program will rouse opposition because it runs counter to the value judgments of some part of the community is hardly irrelevant in the planning of mission-oriented agencies.

It is on this point that the mission-oriented governmental agency is confronted with one of the dilemmas of the American political process. There is still considerable adherence to the doctrine that value judgments are the prerogative of Congress and that the bureaucracy implements programs consistent with those judgments. Agencies hesitate to establish identifiable, wholly effective capabilities for selecting and implementing their own value judgments.

If analysis had nothing to contribute to the formulation and implementation of value judgment, this would not be serious--but it has. Persons in agencies concerned with value judgments rarely have much analytical support for this part of their function. The process is an under-wraps activity of top administrators and political appointees whose status gives them a special basis for the exercise of value judgments. Perhaps their most available forums are coequals from other agencies, although performance may be seriously handicapped by interagency rivalries.

The points made above suggest that no single technology assessment is likely to be satisfactory to the entire structure of decision makers. Public decision making is structured; within the executive branch there is a hierarchy of task and mission-oriented agencies which differ in their prescribed area of activity. Offices lower in the hierarchy generally have restricted areas of operation and mission. The principal thrust of their effort must inevitably be on carrying forward the program which is their principal assigned responsibility. Performance will be judged in those terms.

In short, technology assessment directed to mission-oriented agencies must be restricted to the scope of agency interest and responsibility; otherwise it loses relevance to that agency. But, from a public point of view, assessment in these terms is too narrow. A management-oriented approach to analysis means also limiting the depth of analysis to the point where reasonable bases for management decisions have been provided. Analysis on this basis often lacks completeness and elegance. Some part of these faults can be remedied through technology assessments produced for elements of government with multi-agency points of view. At the apex, within the executive branch, and the client for truly broad technology assessments, is the President and the executive office.

Taken as an entity, the Congress might be considered to be the client for broadly oriented technology assessment, and the general public for even broader efforts. But to view the Congress and the public as entities is surely an error. The principal work of the Congress is in committees, and the client in Congress for technology assessments is not primarily the Congress as a whole, but various committees. As their functional areas are limited so are the scope of the technology assessments which will appear to them to be relevant. There are, to be sure, Congressional committees which habitually take broad points of view and for whom broadly oriented technology assessments will appear to be relevant. Much the same problem would appear to exist with respect to the public. Nonetheless, given our political processes, the public audience for technology assessment cannot be neglected if technology assessment is to fulfill its promise; and the means by which the public can be reached are as yet unresolved.

The relationship between the programs and actions of governmental agencies and the milieu in which government acts will ultimately have much to do with the contribution made by technology assessment. Relationships between the character of government programs and second-order effects are often subtle. For example, prohibition of liquor, narcotics or cigarettes tend to create black markets, to support a criminal element which in turn corrupts others. These effects are, quite appropriately considered second-order effects of any kind of prohibition.

An additional determinant is the degree to which the social needs to which programs and sought-for first order effects are satisfied. So long as the need is desperate and pressing, it will be difficult to convince many that second-order effects need to be taken seriously.

In Summary

In summary, it is a mere platitude to note that society is ever changing its techniques, and that the effect of the changes are far-reaching. What is new is the effort to predict the whole structure of change, to evaluate it, and to identify the best of the apparently-available alternatives. It is perhaps too early to say that there is new emphasis on implementing the results of such assessments of technology, though clearly there is a new determination to preserve what is best in our environment.

As yet, this determination has been poorly focused, short on analytical support, and uncertain as to how to make the tradeoffs among desirable alternatives. In the emphasis on evaluating the consequences of scientific research the proponents of technology assessment may very well have made a sound strategic decision, but the impact of change from other causes is often equally important and so inextricably bound up with science that it is not really useful to restrict technology assessment to the products of science.

Potentially one of the more serious shortcomings of technology assessment may be an unawareness of important second-order relationships.

It would seem that a far-reaching preliminary search for possible relationships should proceed analysis in depth. Following this, the main thrust of analysis must be problem oriented, must avoid being discipline-bound, and must be comparable in structure to systems analysis. System models, the framework of such analyses, typically are simplifications achieved by explicitly setting aside second-order effects, and because these are the heart of technology assessment, a different modelling approach is called for.

Technology assessment must not attempt impossible precision. The structure of the future consequences is largely stochastic, meaning that an array of possible outcomes, appended by probability estimates, should be the sought-for result. Forecasts and predictions developed in this way lend themselves readily to the methods of decision theory which may well become a basic element of technology assessment.

The means by which technology assessment can be integrated into decision making are still unresolved, and crucial. Let us hope that there will be no repetition of the experience of planning, in which the results of analysis have so often been ignored.

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This is a collection of the testimony at the first seminar

on technology assessment. Among the participants were: Louis H. Mayo, Melvin Kranzberg, E.G. Mesthene, A. Hunter Dupree, Alan T. Waterman, and Dael Wolfle.

U.S. Congress. House Committee on Science and Astronautics. "Technology Assessment." Hearings before the Subcommittee on Science, Research, and Development, November 18 and December 2,3,4,8 and 12, 1969, 91st Congress, first session. Washington, U.S. Government Printing Office, 1970, 501 pages. Hearings held subsequent to publication of the subcommittee's three commissioned reports on technology assessment. Among those testifying were: Dr. W.D. McElroy, Director, NSF: Dr. L. Quincy Mumford, Librarian of Congress; Dr. Myron Tribus, Assistant Secretary of Commerce for Science and Technology; Dr. Louis H. Mayo, Director, Program of Policy Studies in Science and Technology, George Washington University; Dr. Lee A. Dubridge, Director, Office of Science and Technology.

U.S. Congress. House Committee on Science and Astronautics. "A Technology Assessment System for the Executive Branch." Report of the National Academy of Public Administration, July 1970. Washington, U.S. Government Printing Office, 1969, 85 pages.
This report proposes that technology assessment become part of the responsibility of federal agencies at the working level. Like budgeting, technology assessment would be integrated into a complete report at the department level. But this completed assessment would not be submitted to the Office of Management and Budget. Instead it would go to an expanded Council on Environmental Quality which would work in concert with the OMB.

U.S. Congress. House Committee on Science and Astronautics. "Technical Information for Congress." Report to the Subcommittee on Science, Research, and Development; prepared by the Science Policy Research Division, Legislative Reference Service, Library of Congress. April 25, 1969. 91st Congress, first session. House Document No. 91-137. Washington, U.S. Government Printing Office, 1969, 521 pages. This study examines several technical areas and programs in which Congress was involved, and extracts from the discussion of these cases some of the salient aspects, needs, and mechanisms for collecting, analyzing, and applying technical information for political decision making.

U.S. Congress. House Committee on Science and Astronautics. "Technology: Processes of Assessment and Choice." Report of the National Academy of Sciences, July, 1969. Washington, U.S. Government Printing Office, 1969, 163 pages. This study concentrates on the structuring of the technology assessment function within the federal government. The panel urges the creation of a constellation of organizations, with components located strategically within both political branches, that can create a focus and a forum for responsible technology assessment activities throughout government and the private sector.

U.S. Congress. Senate Committee on Government Operations. "Establish a Select Committee on Technology and the Human Environment." Hearings before the Subcommittee on Intergovernmental Relations on S. Res. 78, to establish a select Senate Committee on Technology and the Human Environment. March 4,5, and 6, April 24, and May 7, 1969. 91st Congress, first session. Washington, U.S. Government Printing Office, 1969, 334 pages.
This collection of testimony before the Subcommittee on a Select Committee which would be a "central forum in the Senate to investigate the future impact of science and technology." Among those testifying were: R. Buchminster Fuller; Dr. E.G. Mesthene; Dr. Louis H. Mayo; Harvey Brooks; Herbert A. Simon; Barry Commoner; and Jerome Wiesner.

Winner, Langdon. "On Criticizing Technology." Prepared for delivery at the 66th annual Meeting of the American Political Science Association, September 8-12, 1970.
Dr. Winner suggests that technology assessment may not go "far enough" in its critique of technology. He suggests some considerations that have been overlooked by the technology assessors.

Wolf, Harry, editor. "Effects of Technological Development." Executive Seminar Center, Berkeley, California, Mimeo, 1970, 191 pages.
This includes items by C.P. Snow; Jerome D. Frank; Charles W. Sherwin; Avery Leiserson; and J. Herbert Hollomon.

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15. Supplementary Notes

16. Abstracts

Technology assessment is evaluation of change, whether or not the result of science and engineering. The analytical methods of the natural and social sciences, jurisprudence, etc., are used. It integrates analysis in several disciplinary traditions, is predictive, focuses on the obscure at a time when objectives are not clearly formulated, when data and functional relationships are unavailable. Uncovering unsuspected relationships is crucial, since there can be no analysis until a research question is formulated. The inherent uncertainty of the future suggests the use of decision theoretical models. As one element of program analysis, technology assessments must be intergated into a larger analysis. Relevance is a key factor, and what is relevant depends on the orientation of the organization. Technology assessments for different organizations must therefore differ if they are to be effective.

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