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# Technology Assessment in a Dialetic Key

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# TECHNOLOGY ASSESSMENT IN A DIALECTIC KEY

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## Abstract

Technology and institutions interact dialectically. Institutional factors affect the range of alternatives considered by innovators, the resolution of disputes over the consequences of innovation, and even the efficiency of technical projects. Thus, technological impacts are determined in the arena of institutional choice just as much as in the laboratory and on the drawing board. Examples from the fields of medical care, nuclear power generation, and broadcasting technology are used here to illustrate this interdependence. Dialectic thinking, in the Greek sense of a systematic critique of assumptions, arguments, and conclusions is necessary to counteract institutional and conceptual biases, and to support unconventional approaches. As the current interest in adversary proceedings and other dialectic modes of discourse shows, the narrow paradigm of decisionism is being replaced by quasi-jurisprudential methods for assessing the adequacy of arguments, the strength of evidence, and the intrinsic limitations of technical solutions.

## TECHNOLOGY ASSESSMENT IN A DIALECTIC KEY

Scientists and technologists have discovered the virtues of the adversary process. Faced with issues like the effects of nitric oxide exhausts from SST engines on stratospheric ozone, the health hazards of low-level radiation, or the reliability of the emergency core-cooling system of a reactor, they admit that science (today's science, at any rate) is not in a position to provide unambiguous answers. And they further acknowledge that where science and policy meet, conflicting opinions can be legitimately held and fruitfully debated by equally reputable experts. "The adversary process" physicist Alvin Weinberg writes, "Undoubtedly has considerable merit in forcing scientists to be more honest, to say where science ends and trans-science begins, as well as to help weigh the ethical issues which underlie whatever choices the society makes between technological alternatives."[1]

It is important to appreciate the significance of this development, for it marks a departure from beliefs and attitudes that have dominated scientific and technological thinking for more than three hundred years. Bacon, for example, demanded that all preconceived notions, opinions, even words "be abjured and renounced with firm and solemn resolution, and the understanding must be completely freed and cleared of them". "Disputation" -- the art of dialectic argument created by the Greeks and further developed by the scholastic philosophers -- must be rejected, since truth cannot emerge from the clash of opinions, nor nature be conquered with words (*Novum Organon*, passim).

Suspicion of opinion and argument is not the characteristic of the empiricist tradition alone, however. The rationalist Descartes considered "almost as false whatever was only probable" and disagreement a sure sign of error. In a famous passage of the *Regulae ad Directionem Ingenii* he writes (Regula II): "Every time two men make a contrary judgment about the same matter, it is certain that one of them is mistaken. What is more, neither of them possesses the truth, for if one of them had a clear and precise view of the truth, he would be able to expound it to his opponent so as to force the latter's conviction".

Technology assessment always involves questions of a type that Weinberg has termed trans-scientific: questions that can be stated in technical terms but that are beyond the capacity of science to answer. Hence, disagreement among experts is to be expected whenever policy-relevant scientific and technical questions are debated. Conflict of opinions need not lead to confusion. It can be used creatively -- not by concealing it, but by bringing it out into the open;

not by placing it outside the pale of rational discourse, but by increasing the flexibility of our analytic techniques.

When Protagoras taught that there are two opposite arguments on every question, his more orthodox contemporaries were so shocked that the word sophist came to acquire the pejorative meaning that it has maintained to our day. Yet, Aristotle recognized the methodological significance of Protagoras's "double arguments," and concluded (*Rhetoric* I.i.12) that "the orator should be able to prove opposites, as in logical arguments; not that we should do both (for one ought not to persuade people to do what is wrong), but that the real state of the case may not escape us, and that we ourselves may be able to counteract false arguments, if another makes an unfair use of them. Rhetoric and Dialectic alone of all the arts prove opposites; for both are equally concerned with them."

Thus, recognition of the essential ambiguity of our knowledge led to the development of dialectic as a method of argumentation characterized not so much by the form of reasoning (though discussion by way of questions and answers came to be regarded as its paradigmatic form), as by the epistemological status of its premises. Logic and science start from true or evident premises, while the premises of dialectic are only probable. Scientific disciplines are specialized forms of knowledge, but dialectic and rhetoric "both have to do with matters that are in a manner within the cognizance of all men and not confined to any special science. Hence all men in a manner have a share of both; for all, up to a certain point, endeavor to criticize or uphold an argument, to defend themselves or to accuse." (*Rhetoric* I.i.1).

The adversary process is one institutional realization of the dialectic method, but not the only possible one. Indeed, the main thesis of the present paper is that dialectic thinking, in the Greek sense of a systematic critique of assumptions, arguments, and conclusions, should pervade all stages of technology assessment. Formal models and techniques of analysis have a role to play, too, but they are in themselves incapable of inspiring that conflict of views and spirit of self-criticism among innovators that a recent authoritative British report considers as the major goal of technology assessment.[2] Before this goal can be achieved, a number of institutional and conceptual obstacles will have to be overcome. Particularly important among these, though seldom mentioned, are certain biases built into the very structure of technological thinking. They are discussed in the following section.

## Technological Biases

Technology is prescriptive: it teaches how to achieve practical results by following precisely specified rules. A set of computer instructions is probably the best example of technology speaking in imperatives. Elaborate systems can be designed, constructed, and successfully operated -- as long as certain narrowly defined conditions are satisfied. If these conditions are violated, adherence to the rules no longer guarantees success. Thus, technical precepts are "rules of rightness" that account for the successful working of a system but leave its failure entirely unexplained.[3]

The collapse of a bridge, the crash of an airliner, the breakdown of the safety systems of an atomic reactor (due perhaps to nothing more spectacular than the flame of a candle setting fire to the controlling cables) represent violations of the model of a smoothly functioning machine that cannot be understood within the framework of the technical prescriptions. For this reason, commissions inquiring into the causes of technical failures always include a far broader range of expertise than that commanded by the specialists in the technology that has failed.

This peculiar one-sidedness of technological thinking becomes even more pronounced as technologies increasingly rely on the latest advances in design and in mathematical modeling. For, paradoxically, "if the practical system does not yet operate properly, its mathematical model composed of idealized elements will not offer any clues permitting one to locate the cause of trouble."[4] Thus, in spite of its spectacular achievements, modern technology remains peculiarly vulnerable to unsatisfactory performance or disastrous failure.

The reluctance of technology to consider the possibility of failure can also be seen in the fact that "even though much of society's safety management rests with technically trained people, most of them have no special education and expertise in the concepts or practices of safety decisions per se. Worse, they may not even be sensitized to the problems."[5] It is true that some of today's most advanced technologies are highly risk conscious. For example, nuclear engineers construct scenarios of how a catastrophe might occur, and then attempt to devise appropriate countermeasures for each step in the chain of failures. The process has advanced to the point where, according to a well-known expert, "reactors now, at least in the United States, are loaded down with safety system added to safety system -- the safety and emergency systems almost dominate the whole technology."[6] But aside from the impossibility of foreseeing every possible mode of failure (as shown by the case of the candle setting fire to the cables controlling the reactor at Browns Ferry), it should be noted that the risk consciousness of nuclear engineering is largely the result of the pressure of public opinion. Where nuclear technology has been allowed to develop according to its own inner logic, unhampered by criticism and public concern, it has produced few of the safety features (such as containment shells for pressurized water reactors) that are now standard in the United States. Some other sources of technological bias may be mentioned. Reductionism, the view that effective understanding of a complex system can be achieved by investigating the properties of its isolated components, helps to explain the ecological failures of technology.[7] Narrow considerations of efficiency focus attention on the technical characteristics of a proposed solution, often with serious political, institutional, and even economic consequences. And, quite naturally, the technical innovator is biased in the assessment of his project. His initial assumption is that the innovation will achieve what he claims for it and that it will not have any negative consequences that could reduce the attractiveness of its practical implementation.[8]

Three independent systems of assessment have traditionally played a role in controlling the more serious consequences of technological bias: science, the marketplace, and professional opinion. However, their inadequacy in preventing major ecological and human problems is becoming increasingly clear.

Science can foresee and explain some causes of technical failures by specifying the physical conditions under which the components of a system can fulfill their functions, but it cannot prevent the miscalculations that result from human error, lack of information, or incompetent applications of a sound theory. Thus, a well-tested theory for transmission networks of electric power did not prevent the blackout that hit the northeast United States in November 1965. As it turned out, the parameters for the operating thresholds of the circuit breakers had been wrongly selected and the differential safeguarding devices wrongly staggered. More recently, the "catastrophe" of the advanced gas-cooled reactor in Great Britain was mainly due to failure to make allowances for the effects introduced by scaling up from a prototype.

Considerations of economic profitability, supported by the sanctions of a competitive market, have been in the past an important, if partial and imperfect, source of outside control. But the value of the economic yardstick has been seriously eroded in the "contract state", where

> "the great bulk of government billions is distributed by negotiated contracts or sole course contracts on a cost-plus basis, or both ... and research and development unlocks the door for prime contractor status, systems management, and hardware

production. The number of major contractors competing is increasingly reduced, their holdings in both the government and commercial markets increasingly augmented, their relationships increasingly interlocked."[9]

The role of independent professional opinion has likewise lost its former importance. This can be ascribed to a number of concomitant factors, among which the sheer scale of many modern technological projects assumes special importance. Even in a large country a major project "often demands such immense human resources that the manufacturing organization practically monopolizes the employment and commitment of all the relevant experts, thus seriously distorting the normal processes of assessment and licensing for use."[10] Particularly in the United States, the tendency for a large portion of the available scientific and technical manpower to concentrate around a few projects has been further favored by the industrial practice of "stockpiling" manpower with special skills in order to improve the chances of getting government contracts.[11]

At any rate, peer review suffers from intrinsic limitations, since specialists in a given field tend to adopt the same implicit assumptions in criticizing each other's work. Hence, their assessment criteria put a premium on conformity to the rules generally accepted by the profession, rather than testing the validity and broader significance of the rules themselves.[12]

Traditional forms of monitoring cannot be relied upon to discover the characteristic weaknesses and modes of failure of new technological developments; much less can they be relied upon for assessing broad societal impacts. New ways of institutionalizing a critical attitude at all levels of policymaking will have to be invented. Public participation can play an important role here, together with organizational control procedures such as those discussed by Martin Landau in an important paper on self-correcting organizations.[13] A clear realization of the peculiar vulnerability of modern technology is essential since policymakers are prone to discount the uncertainties present in many innovations. As the record shows, a number of new and expensive technologies, from coronary care units to PPBS, have been introduced on a large scale without sufficient evidence of their effectiveness.

## Effectiveness and Efficiency

According to some authors, assessment of efficiency or technical feasibility is a totally different form of assessment from the examination of long-range societal consequences of technical innovation. Different approaches and assessment mechanisms are allegedly appropriate in the two cases.[14] Such a sharp distinction, however, is neither conceptually nor practically justified.

Technology assessment moves along a ladder whose last rungs -- determination of the state of society, identification of impact areas, and evaluation of higher-order consequences of a particular project -- are only dimly perceived from below. Without a firm foothold, it is extremely dangerous to reach out for the higher rungs, for we may be left dangling from a few more or less plausible sociological assumptions. As a matter of fact, it is hardly possible to estimate the higher-order consequences of a technological innovation without specific hypotheses about the likely degree of achievement of its immediate objectives. This simple truth is often forgotten because of the usual, but risky, assumption that the system will perform as advertised. Even this statement is not precise enough, as one must distinguish between two measures of success: effectiveness and efficiency. Effectiveness essentially measures the performance (technical feasibility) of a system under controlled conditions; efficiency is a measure of performance under actual, full-scale conditions.[15] A technology can be effective without being efficient. For instance, a medical action, such as transplant surgery, which is effective in improving the natural history of a disease, may be inefficient because of resource, ethical, or institutional constraints.[16] Or a technology may become inefficient, while remaining effective, because of a greatly expanded level of use (the automobile, some pesticides); inadequate managerial and social skills (as in the case of many technology transfers); lack of suitable institutional arrangements (microwave communication and, possibly, nuclear power generation); or because of sudden changes in socioeconomic parameters (prices of raw materials, population growth, societal preferences).

It is often assumed that the theory and practice of scientific and industrial testing are sufficiently developed to screen out ineffective procedures. Actually, the field of medical care demonstrates how widely publicized innovations are often adopted without adequate proof of effectiveness. For instance, expensive coronary care units have been introduced on the basis of methodologically questionable evidence concerning their effectiveness on case-fatality rates, but under "a great deal of bias, and a considerable amount of vested interests."[17]

Again, multiphasic screening can discover many abnormalities, but there is little evidence that such discoveries lead to a better prognosis for the patients. Thus, after reviewing a number of studies reporting the experiences of patients who had undergone some form of early disease-detecting procedures, an investigator concludes: "The evidence adduced by these studies for or against the effectiveness of multiphasic screening can hardly be considered definitive."[18] More generally, a number of knowledgeable, and not necessarily radical, critics of present health policies argue that comparatively little of medical care is effective and that further development of medical therapies should be deferred until more conclusive proof (preferably through randomized control trials) of their effectiveness is available.[19]

If assessing the effectiveness of technological innovations is still a rather undeveloped function, and is moreover, poorly integrated with other aspects of technology assessment, monitoring of technological efficiency is almost nonexistent. In fact, the concept of efficiency does not usually explicitly appear in the literature of technology assessment. In a sense, this is understandable. The writers in this field have been so concerned about the impacts of technology on society that they have lost sight of the other element of the dialectic dyad: the effect of social institutions on technology.

## Institutional Determinants of Efficiency

In the Hungary of the 1920s, Michael Polanyi watched "a new, imported machine for blowing electric lamp bulbs, the exact counterpart of which was operating successfully in Germany, failing for a whole year to produce a single flawless bulb."[20] Recently, plans to construct a nuclear energy plant at Marviken, Sweden, had to be abandoned after seven years of efforts and an investment of more than 100 million dollars, because of failure to make the reactor critical. This failure, due to managerial and technical incompetence, took place some three decades after Fermi's successful experiment at Stagg Field; the design of the reactor was not even particularly advanced.[21] Such episodes illustrate the difference between the abstract notion of technical effectiveness, or feasibility, and the socially determined nature of efficiency. Technology does not exist in a vacuum. Effectiveness can be investigated in purely scientific and technical terms -- through laboratory testing, the use of prototypes, or randomized control trials. But once effectiveness has been established, the other stages of the assessment process cannot be treated independently of the institutional framework within which the technology is expected to function. This is particularly true in the case of efficiency, since the very possibility of large-scale use of a technical innovation crucially depends on the prevailing institutional arrangements. For all its obviousness, this point is so often forgotten in practice that a short discussion of some specific examples may be justified. The first example deals with nuclear technology, more specifically with the institutional dimensions of the disposal of radioactive waste materials. "When nuclear energy was small and experimental and unimportant," Alvin Weinberg writes, "the intricate moral and institutional demands of a full committment to it could be ignored or not taken seriously. Now that nuclear energy is on the verge of becoming our dominant form of energy, such questions as the adequacy of human institutions to deal with this marvelous new kind of fire must be asked, and answered, soberly and responsibly."[22]

To appreciate the novelty of the waste disposal problem, one should consider the fact that the fissile plutonium (Pu-239) used as regenerating catalyst in breeder reactors and then appearing in radioactive waste, has a half-life[23] of 24,400 years and hence will be dangerous for something like 200,000 years. Even in the case of the common fission products, strontium-90, with a half-life of 28 years, and caesium-137, with a half-life of 30 years, the isolation period required is about 600 years. The reactor itself, when it reaches the end of its useful life through mechanical breakdown, wearing out, or corrosion, becomes the biggest waste product of all and must be kept under surveillance against human entry for at least 200 years.

Different methods of sequestering radioactive wastes have been proposed, from permanent storage in vaults to disposal in geological strata, particularly in bedded salt. Whichever method is used, the wastes will have to be kept under surveillance essentially in perpetuity. Herein lies the crucial problem, since the need for perpetual control demands a longevity of social institutions without precedent in human history. The controversies raging in every country that has entered the nuclear age indicate that the public will not accept a largescale use of nuclear power technology as long as the institutional problems remain unsolved. One is reminded of the conclusion reached by Karl Wittfogel in his massive study of the "hydraulic societies" of the past: whether a new level in the transformation of the natural environment can be attained at all, or, once attained, where it will lead, depends primarily on the institutional order.[24]

Use of the electromagnetic spectrum for radio and TV broadcasting presents technical problems that are obviously different from those of nuclear engineering; but the impact of institutional factors on technical efficiency is just as evident. Before 1927, when Congress decreed that the rights to the use of the frequency spectrum were to be allocated by the Federal Radio Commission (forerunner of the Federal Communications Commission, established in 1934), anyone in the United States could set up a radio transmitter and broadcast on any frequency he chose, regardless of who else was broadcasting on the same or neighboring frequencies. Chaos resulted, not because of any inherently peculiar technological characteristics of radio emissions, but because the rights to the use of the frequency spectrum were ill-defined.

The solution adopted by Congress has been criticized by a number of economists both on grounds of allocative efficiency and because, they argue, the "unsatisfactory" performance of radio and TV is actually the result of a legal structure that denies salability of information by radio frequency.[25] Whether the frequency spectrum should be allocated through the market, as advocated by these economists, or by central controls is not, of course, a pertinent issue for the present discussion, except insofar as it exemplifies again how technical performance depends on institutional factors.

The same type of dependence can be observed in recent developments in solid-state microwave devices. This technology has been successfully used for over 30 years on a rather limited scale and, because of mass production, could now proliferate on a scale comparable to that of television.[26] However, under present institutional arrangements, which were designed for controlling the use of a few tens of thousands of units, such an expansion would entail serious losses of efficiency due to congestion of parts of the electromagnetic spectrum. Thus, more flexible forms of control than the block-allocation system used by the FCC will have to be devised if microwave systems are to be used on the scale permitted by today's technology and economics.

As these examples suggest, it is misleading to speak of technology and its consequences as if these terms had a well-defined meaning, independent of the existing institutional constraints. Hence, a complete technology assessment must take into consideration both sides of the dialectic relationship between social institutions and technology. A more detailed analysis than is possible here would also show how developers, operators, and beneficiaries of a particular technology attempt to gain a less constrained use of it by manipulating the relevant portion of the institutional framework. The nature of technological impacts is determined in the arena of institutional choice just as much as in the laboratory and on the drawing board. We cannot assess technology without, at the same time, evaluating institutions.

## Technological Alternatives

All methodological guidelines for technology assessment stress the importance of examining alternatives. The emphasis varies from an overly ambitious "presentation of complete alternative options for action"[27] to the narrow prescription to "identify alternative strategies to solve the selected problems with the technology under assessment."[28]

In discussing alternatives, it is not the number but the variety of the options considered that is important. All too often, only variants of the same basic approach are given serious attention. For instance, the National Academy of Engineering's assessment of teaching aids identifies four strategies, but three of these are based simply on different funding levels. The study of multiphasic health screening (MHS) conducted by the same institution does not go beyond the observation that existing MHS centers

> range from office (or mobile units) in which a number of different physical examination tests are given in a very personal, individualized, and traditional manner, to highly automated centers in which the flow of patients through up to 30 testing stations is scheduled and planned according to the best principles of operations research, with the test results fed to a computer that develops for the physician a panoramic picture of the patient's health status. Just as the degree of automation varies widely, the number of patients handled ranges from a few thousand to 30,000 per year.[29]

The authors justify the limited scope of the MHS study with the statement that "the available data base was not sufficiently developed to permit meaningful definition of alternative strategies." But the problem is not only, or even primarily, lack of data. For the study fails to make clear that the assessment criteria depend on which of two alternative philosophies of MHS is adopted: (a) it is seen merely as a multiple screening program, or (b) it is seen as the basis of an alternative method of delivering primary care -- one in which prevention becomes an important characteristic of the health care system.[30]

Powerful economic, institutional, and professional interests combine to restrict the range of truly different options that are presented to policymakers, or even given serious consideration by the experts. When, a few years ago, Linus Pauling suggested that the National Cancer Institute allocate a small portion of its budget to "unconventional research", his plea was largely ignored by the cancer research establishment.[31] And in spite of mounting evidence that most human cancers are environmentally induced or related, expenditures on environmental carcinogens have a low priority in the NCI's budget.

This reluctance to explore new research approaches is probably not unrelated to the fact that the generals of the "war on cancer" have been trained in surgery, biochemistry, radiology, and virology. According to Samuel Epstein,[32] "none of the three members of the President's Cancer Panel or of the twenty odd members of the 1975 National Cancer Advisory Board appears to have significant professional qualifications or experience in epidemiology and preventive medicine, and only one is authoritative in chemical carcinogenesis." Like all generals, these specialists are better equipped to fight the last war, as seen through the spectacles of their respective disciplines, than to recognize the new environmental and socioeconomic dimensions of the cancer problem.

This phenomenon is, of course, quite general. Any established scientific paradigm tends to become parochial in its range of interests and choice of tools, and intolerant of inconsistencies. Thus, western allopathic medicine has long refused to accept Chinese acupuncture, whose effectiveness as an anesthetic agent and in the treatment of certain diseases is now acknowledged, largely because acupuncture is inconsistent with allopathic theory and practice.

Technology assessors must learn to accept conflict among mutually incompatible viewpoints, for only in this way can really new insights be gained. But unconventional alternatives can hardly survive in an environment dominated by entrenched techno-scientific bureaucracies and powerful schools with strong professional and intellectual committments. Although the examples in this section have been taken from medicine, no field of science and technology is immune from the dangers of dogmatism and chauvinism.

Rejection of any form of outside interference has served an important ideological function in the early development of modern science. Today the question is: who can protect unorthodox ideas from the opposition of some of the strongest institutions of contemporary society? The counterforce necessary to overcome scientific-technical parochialism and institutional inertia may have to be political. A politically stimulated multiplicity of approaches in applied science and technology may well be the most significant contribution of technology assessment to human welfare.[33]

In comparing alternatives, it is also important to keep in mind that ideas in agreement with accepted doctrines and their institutional embodiments enjoy a great comparative advantage over unconventional approaches. In fact, the very standards of assessment have been patterned after the prevailing conceptions and molded by existing institutions; and what are counted as acceptable data and relevant evidence is determined by methodological rules that have been distilled from current practice.

The ancient dialecticians knew that to keep competing alternatives alive it is often necessary, in Protagoras' words, to "make the weaker case the stronger." For only by making a serious effort to understand the inner logic of an unconventional approach, by improving it and visualizing conditions under which it may prove successful, is it possible to compensate for the built-in advantages of the more orthodox views.

## Dialectics of Assessment

"The major goal of technology assessment is not to ensure certainty, but to inspire a conflict of views that will maintain a spirit of healthy self-criticism amongst the innovators."[34] Even this modest view of technology assessment, too modest perhaps for the advocates of "total systems assessment," requires significant changes in the prevailing conceptual paradigms and modes of analysis.

At the conceptual level, nothing less is involved than the rejection of an intellectual tradition that arbitrarily restricts the domain of rationality to self-evident truths and "objective," indisputable facts. To one who believes, with Bacon and Descartes, that truth is manifest, criticism seems superfluous, and controversy is a sign of ignorance or casuistry. Expertise becomes identical with esoteric knowledge of those aspects of reality that are amenable to the methods of empirical science.

People raised in this tradition are prone to think of technology assessment as a sort of bootstrap operation, "a technology in itself ... for measuring and monitoring social performance,"[35] a function to be performed exclusively "by experts; that is, by people who have demonstrated substantial contributions to technology and technology related areas."[36] They advocate "neutral and objective"[37] assessments, without realizing that even scientific objectivity results not from the attempts of individual scientists to be objective, but from what Karl Popper calls the friendly-hostile cooperation of many scientists.[38] Objectivity is the product of social institutions designed to facilitate mutual criticism and the public control of results, rather than a psychological characteristic of the detached expert.

Decisionism, the "vision of a limited number of political actors engaged in making calculated choices among clearly conceived alternatives"[39] is the other paradigm that has strongly influenced the methodological development of technology assessment.

With its emphasis on synoptic and value-free analysis, on technocratic elitism, and on politics as decision making, decisionism accords very well with the prevailing metaphysics, which prizes above all what can be quantified and formally manipulated. It leads, quite naturally, to viewing technology assessment as "neutral and objective, seeking to enrich the information for management decision," a "systematic, comprehensive, objective value-free analysis of the consequences of technological applications for society."[40] Identifying possible outcomes, evaluating their probabilities, developing a data base, estimating the utility and disutility of each outcome to the interested parties: these are, supposedly, the essential steps of decision-oriented technology assessment. All that is left for the decision maker is "weighing the utilities and disutilities to the interested parties and deciding if the policy alternative is better than other alternatives."[41]

But in the context of technology assessment, the decision model is no more than an analogy, and a misleading one at that. It is reasonable to attempt to optimize a choice among well-defined alternatives when the objective function can be specified and the basic parameters and other input data are known with sufficient precision. But these conditions are never satisfied in technology assessment studies. Statements like "determining the direction of technology's development," "developing alternate directions," or "determining the state of society" cannot possibly be interpreted literally, in the sense that the analyst is expected to represent or forecast specific states or paths of development. Whatever concrete meaning can be given to these expressions has to do, I submit, with the investigation of the constraints under which some goals are ruled out, while others *may* be achieved. Thus it is safe to assume that no technological breakthrough will produce a machine that is one-hundred-percent effective, for this would amount to a violation of the second law of thermodynamics.

Similarly, the "state" of society cannot be determined by listing all its constituent elements and forms of activity. What one can attempt to determine is the range of feasible options that are open to it, within the limitations set by existing technical, economic, and institutional constraints.[42] Every society lives in a constant dialectic tension between goals and constraints. Analysis can help to clarify the nature of the constraints and suggest ways to reduce the tension, either by relaxing some of the constraints (if this is at all possible) or by modifying the goals[43]. These are uncongenial tasks for decisionism, both as a conceptual paradigm and as a set of formal optimization techniques.

The major problems of technology assessment today are institutional and procedural, not ones of optimization: how to make effective citizen participation possible; how to design mechanisms, such as "science courts," to resolve disagreement among experts; how to educate the public and stimulate self-criticism among specialists. The narrow rationality of "scientific decision making" must be replaced by quasi-jurisprudential methods for assessing the adequacy of arguments, the strength of evidence, the intrinsic limitations of scientific tools, the pitfalls lurking in every technical conclusion. To get to the "truth" the assessor will have to rely not on models and algorithms but on advocacy and the adversary process.[44]

This change of perspectives and methods of inquiry, which is becoming increasingly evident in discussions on technology assessment, marks a return to patterns of discourse developed in antiquity for the purpose of extending the use of reason to the domain of public affairs. Aristotle, and the Sophists before him, clearly saw that the exercise of the rights guaranteed by the polis to its citizens required the systematic use of critical skills "within the cognizance of all men and not confined to any special science." Dialectic reasoning, Aristotle points out, has three main uses. First, it is a method of critical inquiry into the foundations and value premises of the different sciences and techniques. Second, it is a technique for arguing in favor of one's own viewpoint and a procedure for clarifying controversial issues, since "if we are able to raise difficulties on both sides, we shall more easily discern both truth and falsehood on every point" (*Topics*, 101 a 37). Finally, and most importantly, dialectic is an educational process that transforms the common man into an informed citizen and the specialist into a person able to communicate with his fellow citizens. It is, in Plato's words, the "science of free men" (*Sophist*, 253 c).

## Notes


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8 Council for Science and Technology, op.cit., p. 31

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[12] Alvin M. Weinberg, "Criteria of Scientific Choice," *Minerva* I, 2 (Winter, 1963) p. 162.

[13] Martin Landau, "On the Concept of a Self-Correcting Organization," *Public Administration Review*, Vol. 31 (November/December 1973), pp. 533-542.

[14] See, for instance, the discussion following the paper by Richard A. Carpenter, "Technology Assessment and the Congress," in Raphael G. Kasper, editor, *Technology Assessment* (New York: Praeger Publishers, 1972), p. 43

[15] A.L. Cochrane, *Effectiveness and Efficiency* (Nuffield: The Nuffield Provincial Hospitals Trust, 1972), pp. 26-44.

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20 Michael Polanyi, op.cit., p. 52

21 Hannes Alfven, "Science, Technology and the Politico-Economic Power," *Impact of Science on Society*, 22 (January-June, 1972), pp. 85-93.

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23 The half-life of a radioactive material is the time in which half its atoms will decay.

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