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Technological Forecasting and Assessment: Science and/or Mythology?

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ABSTRACT

A number of radically distinct models (inquiry systems) are described. The models derive from C. West Churchman's recent characterization of the history of Western epistemology. It is argued that only a few of these models are appropriate for technological forecasting problems. Most technological forecasting methodologies rest on a dubious philosophical foundation. They unreflectively assume that the inquiry systems which are appropriate for "well-structured" problems are also appropriate for "ill-structured" problems. It is argued that technological forecasting is an inherently ill-structured problem and therefore requires a methodology which is uniquely suited to such problems. The Dialectical and Singerian Inquiring Systems are proposed as particularly appropriate for ill-structured problems.

> The white man drew a small circle in the sand and told the red man, "This is what the Indian knows," and drawing a big circle around the small one, "This is what the white man knows." The Indian took the stick and swept an immense ring around both circles. "This is where the white man and red man know nothing."
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> *The People, Yes*
> Carl Sandburg

Introduction

It is often said, and with great justification, that philosophy is the most basic of all of man's creations. For at the heart of every man's thoughts, actions, and deeds is a philosophy-no matter how crude or unarticulated it may be-which underlies and justifies his every thought, his every action, and his every deed. In the area of technological forecasting and technological assessment this seems to be particularly the case, since we are explicitly dealing with the realm of the uncertain-the future-that which has yet to occur and which no man can predict with absolute certainty.

No matter how well established and technical the field of technological forecasting becomes in its development, it can never become a purely technical or scientific concern. There will always remain at the heart of forecasting a basic philosophical element which

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can never be completely removed. The basic, ineradicable philosophical element is expressed by any one of the following questions:

> What permits us IO extrapolate from the past or present to the future?, What guarantees that the future will behave like the present or past?, and, What firm insurance or what sure guaranteedo we have that the future will behave as our projections (i.e. our models) of it forecast (i.e. predict)?

No matter what approach one takes towards the answering of these questions, one's answers will be indicative of a basic philosophical stance or position. The reason is that one's answer will tend to identify in what fundamental process or force one locates the basic mechanism which for that individual guarantees or insures the predictability of the future. To put this in a different way, one's answer will indicate the criteria that any response will have to satisfy in order to be acceptable or to count as an "Answer." For example, to say that a certain kind and amount of factual evidence will have to be mustered before we can act with confidence with respect to the future is one kind of criterion. Unfortunately, it is also in many senses to beg the question. Since factual evidence itself always holds only for the immediate present or past, such a response already tacitly takes for granted the very thing we are questioning in the first place, i.e., why the factual evidence of the past or present can be relied on to predict the future.

We humans seem to have a fundamental talent for disguising through phraseology the fundamental similarities that exist between common methodologies of a different name. As a result, we often bicker and quarrel about such superficial matters as whether this or that name is appropriate for a certain technique, when the real issue is whether the philosophical system of inquiry that underlies a proposed technique or methodology is sound and appropriate. We are indeed the prisoners of our basic images of reality. Not only are we generally unaware of the different philosophical images that underlie our various technical models, but each of us has a fundamental image of reality that runs so deep that often we are the last to know that we hold it. As a result, we disagree with our fellow man and we experience inner conflict within ourselves without really knowing why. What's worse, we insure this ignorance by hiding behind catch-words and fancy names for techniques. The field of technological forecasting and assessment is no less remiss than many other disciplines in having introduced its own characteristic vocabulary and slang which often serves to cloud fundamental issues.

One of the basic purposes of our discussion is to bring these fundamental differences and conflicts of methodology up to the surface for conscious examination, so that hopefully one can be in a better position to choose explicitly the approach he may wish to adopt.

In order to accomplish this objective we will consider a number of fundamental stances which men have taken towards the problem of predicting the future. More precisely, the purpose of this paper is to examine the variety of ways and mechanisms in which men have chosen to locate the criteria that would "guarantee" our extrapolation from the present to the future. Also, this paper will show that every one of these fundamental ways differs sharply from the others and that each of them has its major strengths as well as its major weaknesses. The moral of the discussion will be that there is no ***one single best way*** of extrapolating or insuring our predictions, in the sense that no mode possesses all of the desirable characteristics that one would like any preferred mode of prediction to possess. As we wish to illustrate, this awareness itself constitutes a kind of strength. To show that there is no one mode of extrapolation that can satisfy our every requirement, i.e. that there is no one mode that is *best* in all senses and for all circumstances, is not to say that each of these modes is not uniquely or better suited for some special set of circumstances.

Since these various modes or characteristic models of prediction basically derive from the history of Western philosophy, another objective of this paper is also to show what each philosophy, and especially, what the philosophy of science, specifically and concretely, has to offer the field of technological forecasting and assessment. Where there is little or no methodology in these forecasting areas that match the fundamental epistomologies, then we may infer existing gaps in the methodology.

Before we describe each of these philosophies, or systems, or inquirers more fully, we can rather easily and simply convey the general spirit of each of them by means of the following exercise. Suppose we are given a set of statements or propositions by some forecaster that pretend to describe what, for example, the world of 1990 will be like. Then our Inquiring Systems can be simply differentiated from one another in terms of the kind of characteristic question each of them would address to the forecaster or to his set of propositions. Each question in effect embodies the major philosophical criterion that would have to be met before that inquirer would accept the forecast.

The Leibnizian analyst or Inquiring System (IS) would ask something like:

> "How can one independent of any empirical considerations give a rational justification of the forecast? What is the model you are using? How was the result deduced and is it precise and certain?"

The Lockean analyst or IS would ask something like:

> "Since data is always prior to the development of theory, how can one independent of any formal model justify the prediction by means of some objective data or the consensus of some group of expert judges that bears on the forecast? What are the statistics? What is the probability you are wrong? Is that a good estimate?"

The Kantian analyst or IS would ask something like:

> '*Since data and theory always exist side by side, does there exist some combination of data or expert judgment plus underlying theoretical justification for the data that would justify the prediction? What alternative or other possible forecasts exist? Which of these satisfy my objectives?"

The Hegelian analyst or IS would ask something like:

> "Since every forecast or set of predictions is a reflection of a more general theory or plan about the nature of the world as a whole system, i.e., a world view, does there exist some alternate sharply differing world view that would permit the serious consideration of a completely opposite forecast? What if the reverse happens and why wouldn't that be better?"

Finally, the Singerian analyst or IS would ask:

> "Have we taken a broad enough perspective of the basic problem? Have we from the very beginning asked the right question of the future? Is that the right objective? To what extent are the questions and models of each inquirer a reflection of the unique personality of each inquirer as much as they are felt to be a''natural'' characteristic or property of the''real'' world?"

Even at this point in the discussion, it should be apparent that as a body these are very different kinds of questions and that each of them is indicative of a fundamentally different philosophy of forecasting. It should also be apparent, and it should really go without saying, that these do not exhaust the universe of potential questions. There are many more philosophical positions and approaches to forecasting than we could possibly hope to deal with in this paper. These positions do represent, however, some of the most significant and major approaches.

The plan of the rest of this paper is briefly as follows: one, we shall describe each inquirer in turn and in general terms, but hopefully in enough detail to give the reader more of a feel for each system; two, along with the description of each inquirer, we shall list some of the major existent forecasting systems and techniques that best seem to serve as operational examples of these various approaches; and finally, three, we shall attempt to point out some general conclusions regarding the nature of forecasting that emerge once our survey of IS has been completed.

It should be borne in mind as we proceed that the question of concern is not how we can know the future with "perfect certainty," for put in this form the answer is clearly that we can't. But then neither can we know all there is to know about the present with "perfect certainty." The real question is what *can we* know of the future, and, even more to the point, how we can justify what we think we know. It is on this very issue that the difference between Inquiring Systems arises.

Inquiring Systems (IS)

The process of inquiry, whether it be for a single individual or a group of individuals, may be represented by a very general system as pictured in Fig. 1. We start with some assumed "external event" or "raw data set" which for the moment we consider to be a characteristic property of the "real world," i.e. the data set "exists" in the "external world." Next we apply some transformation and/or filter to the raw data in order to get it in the "right form" for input to some model. The model, which may be any sort of structured process, is represented by a set of rules, which may be either in the form of an algorithm or a set of heuristic principles. The model acts on the input to transform it from the state of "input data" to the state of "output information." This output information may in turn be passed through another filter or transform to put it in the right form so that a decision-maker can recognize and utilize it as "information" or as a "policy recommendation." In terms of this general configuration, the various IS can be differentiated from one another with respect to (I) the priority assigned to the various systems components in Fig. I, i.e. which components are regarded as more important or fundamental by one IS than by another, and (2) the degree of interdependence assigned to the various systems components by each IS.

Our objective in the following discussion will be to draw a sufficient distinction between the philosophical inquiring concepts to place the technological forecasting and assessment methodologies into this perspective. The annotated bibliography provides sources for those who may be interested in more detailed explanations.

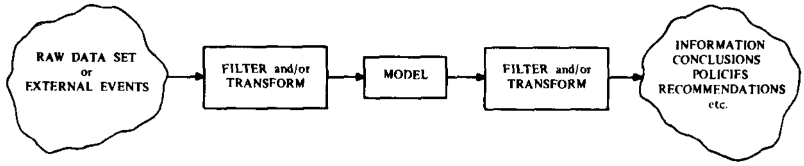

FIG. 1. A model of a generalized information or inquiry system.

LEIBNIZIAN IS

The philosophical mood underlying the major part of theoretical science is that of Leibniz. The sense of Leibnizian inquiry can be rather quickly and generally captured in terms of the following characteristics.

(1) Truth is analytic, i.e., the truth content of a system is associated entirely with its formal content. A mode1 of a system is a formal model and the truth of the model is measured in terms of its ability to offer a theoretical explanation of a wide range of general phenomena and in *our* ability as model-builders to state clearly the formal conditions under which the model holds.

(2) A corollary to (1) is that the truth of the model does not rest upon any external considerations, i.e., upon the raw data of the external world. Leibnizian inquirers regard empirical data as an inherently risky base upon which to found universal conclusions of any kind since from a finite data set one is never justified in inferring any general proposition. The only general propositions that are accepted are those that can be justified through purely rational models and/or arguments. Through a series of similar arguments, Leibnizian *IS* not only regard the formal model component as separate *from the* data input component *but* prior to it as well. Another way to put this is to say that the whole of the Leibnizian IS is contained in the formal sector *and thus it has priority over all the other* components.

In short, Leibnizian IS are the epitome of formal, symbolic systems. For **any** problem, they will characteristically strive to reduce it to a formal mathematical or symbolic representation. They start from a set of elementary, primitive, "formal truths" and from these build up a network of ever-expanding, increasingly more general, formal propositional truths. The *guarantor* of such systems has traditionally been the precise specification of what shall count as a proof for a derived theorem or proposition; other guarantor notions are those of internal consistency, completeness, comprehensiveness, etc. The final information content of Leibnizian IS is identified almost exclusively with its symbolic content.

The "laws" of physics (e.g., force equals the rate of change of momentum) are examples of Leibnizian truths. Also, computer simulation models of industrial processes are typical of the types of Leibnizian approaches that have been comparatively successful as forecasting and planning tools in industry. One can often model a proposed plant or facility to a sufficient degree to predict performance accurately and to utilize the model to examine alternative configurations before actual investments are made.

A prime example of Leibnizian inquiry is the field of Operations Research (OR), in the sense that the major energies of the profession have been almost exclusively directed towards the construction and exploration of highly sophisticated formal models. OR is the prime example of Leibnizian inquiry not because there is no utilization of external data whatsoever in OR models but because in the training of Operations Researchers significantly more attention is paid to teaching students how to build sophisticated models than in teaching them equally sophisticated methods of data collection and analyses.

Two specific Leibnizian approaches in the field of technological forecasting are correlation analysis and substitution analysis. Both of these result from an analogy with classical biological growth models governing such phenomena as the growth of cells and the growth of species. The analogy assumes that like biological phenomena, technological development passes through some fundamental, characteristic phases, e.g., birth, growth, and death. For example, the process that governs the rate of growth of the transfer of technology can be represented as a diffusion of information process, which is very close to the kind of diffusion process that a biological organism goes through in searching some available territory for food. As a result of this kind of model, one may infer that certain kinds of curves that relate to the growth of technology are correlated. A common example of this is the use of the performance of military aircraft at some point in time to infer the performance of civilian aircraft at some later point in the future. The model is used to predict the time it will take military technology to diffuse into the civilian market. There are a large number of correlations of this type in the literature of technological forecasting.

The substitution curve analysis also makes use of the growth analogy but in quite a different way. The same kind of curve that is characteristically used to describe the growth of a biological population in a space of finite resources is also used to describe the percentage of the market that a new technology has and will take over. Substitution analyses are characteristically given in the form of curves or tables which indicate the percentage of substitution that has taken place by a new technology in a certain market in various fixed time periods. The apparent time to go from 10% to 90% substitution is also usually indicated. The rule of thumb on the part of the people who utilize the technique for planning purposes is that by the time the process has reached a substitution level of 15%, the process is usually irreversible and the resulting forecasting curve is a useful projector of things to come.

Typical substitution curves have been exhibited for such things as man-made fibers to natural fibers, water based paints to oil paints, man-made flooring to all flooring, synthetic rubber to natural rubber; margarine to butter, etc.

The Leibnizian character of these models can rather easily be seen by spelling out a number of buried assumptions that underlie their applicability. It should be noted that few of these assumptions are rarely, if ever, made explicit. They seem to be assumed implicitly. For one, it seems to be an implicit assumption that the reason why the forecasts can be relied on to predict the future is because the models reveal or embody a fundamental, enduring, structural feature of reality, e.g., the supposed basic features that govern the growth of biological phenomena. A second assumption is that the models can be widely applied, again because the models supposedly embody a characteristic process that underlies a wide range of technical and social processes. In other words, the assumption is not only that a wide range of processes can ***be*** described in terms of these models but that these models actually underlie the behavior of a large number of processes, i.e., that in some sense the models are real. In this sense, the most fundamental unspoken assumption is that as characteristic features of reality the models make possible the data that is fitted to the models, and that the data do not make possible the models. The models ***are*** really prior to the data in the ***sense*** that they are ***used to uncover the*** kind of data that ***can be*** fitted to ***the models.*** Indeed, the models implicitly assume that for a wide range of phenomena, there can be found the "right kind of data" that will fit the models; hence, the universal applicability of the models is perpetually assured. In this sense, the models take on the tenor of self-fulfilling prophecies. They are always "true" by definition.

For which kinds of problem situations are Leibnizian analyses most appropriate? First of all, the situations must be sufficiently well understood and simple enough so that they can be modeled. Thus, Leibnizian IS are best suited for working on clearly definable (i.e. well-structured) problems for which there exists an analytic formulation as well as solution. Second, the modeler must have strong reasons for believing in the assumptions which underlie Leibnizian inquiry, e.g. that the model is universally and continually applicable. In a basic sense, the fundamental guarantor of Leibnizian inquiry is the "understanding" of the model-builder, i.e. he must have enough faith in his understanding of the situation to believe he has "accurately" and "faithfully" represented it.

The abuses of these techniques usually occur when there is not a good understanding, or no attempt to arrive at such, of the particular causal model underlying a particular correlation or substitution result. Without comprehending the relationships, in the model, that produce the predicted effect, there is always the danger that a sudden change in the nature of the model will invalidate the ability to utilize the projections. For example, some planners in the steel industry utilized predicted GNP in the 60's to predict the growth of certain markets, while others utilized population. In the 60's both GNP and population were largely correlated. However, this may not hold true in the 70's. Also, the beginning substitution of plastics for metals in cars, as estimated by some forecasters, may be affected strongly by or even reversed in direction by the recent shift in emphasis on safety.

There is no way in the correlation or substitution analyses to predict specific technological breakthroughs. Therefore, all predictions based upon these methods hold only until a new technology or new synthesis of technology appears on the scene to begin a new set of curves. For example, predictions based upon core memory technology for computers will not necessarily predict the effect of introducing bubble memory technology. However, once bubble memories are on the market a substitution process may become observable.

Note that there is no sure way to prove or justify the assumptions underlying Leibnizian inquiry. The same is true of all the other IS. But then, this is not the point. The point is to show the kinds of assumptions we are required to make if we wish to employ Leibnizian inquiry so that if the decision-maker or modeler is unwilling to live with these assumptions he will know that another IS may possibly be called for.

LOCKEAN IS

The philosophical mood underlying the major part of empirical science is that of Locke. The sense of Lockean IS can be rather quickly and generally grasped in terms of the following characteristics.

(1) Truth is experiential, i.e.. the truth content of a system is associated entirely with its empirical content. A model of a system is an empirical model and the truth of the model is measured in terms of *our* ability (a) to reduce every complex proposition down to its simple empirical referents (i.e., simple observations) and (b) to insure the validity of each of the simple referents by means of the widespread, freely obtained agreement between different human observers.

(2) A corollary to (1) is that the truth of the model does not rest upon any theoretical considerations, i.e., upon the prior assumption of any theory (this is the equivalent of Locke's *Tabula* Rasa). Lockean inquirers are opposed to the prior presumption of theory, since in their view this exactly reverses the justifiable order of things. Data is that which is prior to and justifies theory, not the other way around. The only general propositions which are accepted are those which can be justified through "direct observation" or have already been so justified previously. In sum, the data input sector is not only prior to the formal model or theory sector but it is separate from *it* as well. The whole of the *Lockean* IS is built up from the data input sector.

In brief, Lockean IS are the epitome of experimental, *consensual* systems. On any problem, they will build an empirical, inductive representation of it. They start from a set of elementary empirical judgments ("raw data," observations, sensations) and from these build up a network of ever-expanding, increasingly more general, networks of factual propositions. Where in a Leibnizian IS the networks are theoretically, deductively derived, in a Lockean IS they are empirically, inductively derived. The guarantor of such systems has traditionally been the function of human agreement, i.e., an empirical generalization is judged "objective," "true," or "factual" if there is sufficient widespread agreement on it by a group of "experts." The final information content of a Lockean IS is identified almost exclusively with its empirical content.

An example of a Lockean methodology is the field of statistics. In essence, statistics places the data in a representation where the data itself votes, in a sense, on its own degree of validity in terms of correlation coefficients, confidence limits, variances, etc. Then a human may judge if the degree of validity is sufficient to infer a prediction. Pure experimentation, in the sense of measuring phenomena, is typical Lockean endeavor. In the social sciences, we often find separate schools of endeavors usually reflecting either largely Lockean or largely Leibnizian approaches. Many of the current generation of predictive economic models are basically Lockean in nature, since many of them rest largely on regression analyses of historical data.

In the field of technological forecasting, trend extrapolation and regression analysis, to mention but two, are simple and common examples of Lockean inquiry. In the typical application of trend extrapolation, the performance over time of various technological meaures (e.g., computer speed, aircraft carrying capacity, material strength, energy production) is plotted and then the curves are "simply extrapolated" to give future trends. Even in the cases where the curve extrapolation procedure is governed by complex mathematical considerations, the whole process is still essentially a Lockean procedure. The reason is that, except for the possibility of statistical considerations, no theoretical model of the underlying phenomenon is used to guide the collection of the initial data or its subsequent analysis, and in this case, the extrapolation procedure. In other words, the activities of theoretical explanation or justification, raw data collection, and curve extrapolation are assumed to be separable or independent of one another. However, in a fundamental sense trend extrapolation cannot be a pure Lockean Inquirer. The process of data collection and data analysis may not be related by an explicit well-developed formal theory, but they are related nonetheless. One cannot consistently maintain that one can know very little of what the future will be like and then turn around and argue that one knows with confidence that such and such a data set is a "relevant" and "reasonable" data base upon which to base a projection of what the future will be like. The point is that to make the judgment that a particular data set is relevant to a projection of the future is thereby to articulate a theory-at the very least, a point of view-with respect to what the future will be like.

A more recent, and certainly by far, a much more interesting example of a Lockean IS is the "consensus" Delphi technique first pioneered by Dalkey, Helmer, and Rescher at RAND. In very simple terms, the Delphi is a procedure for structuring a communication process among a large group of individuals. In assessing the potential development of a technical area, a large group (typically in the tens or hundreds) are asked to "vote" on when they think certain events will occur. One of the major premises underlying the whole approach is the assumption that a large number of expert judgments is required in order to treat adequately any issue. As a result, a face-to-face exchange among the group members would be inefficient or impossible because of the cost and time that would be involved in bringing all the parties together. The procedure is about as pure and perfect a Lockean procedure as one could ever hope to find. For one, the "raw data inputs" are the opinions or judgments of the experts. For another, the validity of the *resulting judgment of the entire group is typically measured in terms of the explicit degree of consensus among the experts.* The thing that serves to distinguish the Delphi from an ordinary polling procedure is the feedback of the information gathered from the group and the opportunity of the individuals to modify or refine their judgments based upon their reaction to the collective views of the group. Secondary characteristics are various degrees of anonymity imposed on the individual, and collective responses to avoid undesirable psychological effects.

The problems associated with the Delphi illustrate the problems associated with Lockean inquiry in general. The judgments that typically survive a Delphi procedure may not be the "best" judgments but rather the minimum compromise position. As a result, the surviving judgments may lack the significance that extreme or conflicting positions may possess.

The strength of Lockean IS lies in their ability to sweep in rich sources of experiential data. In general, the sources are so rich that they literally overwhelm the current analytical capabilities of most Leibnizian systems. The weaknesses, on the other hand, are those that beset all empirical systems. While experience is undoubtedly rich, it can also be extremely fallible and misleading. Further, the "raw data," "facts," or "simple observables" of the empiricist have always on deeper analysis proved to be exceedingly complex and hence further divisible into other entities themselves thought to be indivisible or simple, ad infinitum. More troublesome still is the almost extreme and unreflective reliance on agreement as the sole or major principle for producing information and even truth out of raw data. The trouble with agreement is that its costs can become too prohibitive and agreement itself can become too imposing. It is not that agreement has nothing to recommend it. It is just that agreement is merely one of the many philosophical ways for producing "truth" out of experiential data. The danger with agreement is that it may stifle conflict and debate when they are needed most. As a result, Lockean IS are best suited for working on well-structured problem situations for which there exists a ***strong consensual*** position on "the nature of the problem situation." If these conditions or assumptions cannot be met or justified by the decision-maker-for example, if it seems too risky to base projections of what the future will be like on the judgments of experts, no matter how strong the agreement between them is-then some alternate system of inquiry may be called for, as in the previous case of the Leibnizian inquirer.

KANTIANIS

The last two sections illustrate the difficulties that arise from emphasizing one of the components of a tightly coupled system of inquiry to the detriment of the other components. Leibnizian inquiry emphasizes theory to the detriment of data and Lockean inquiry emphasizes data to the detriment of theory. When these attitudes are translated into professional practice, what often results is the development of highly sophisticated models with little or no concern for the difficult problems associated with the collection of data or the seemingly endless proliferation of data with little regard for the dictates of currently existing models.

The recent controversy surrounding the attempts of Forrester and Meadows to build a "World Model" is a good illustration of the strong differences between these two points of view. In our opinion, the work of Forrester and Meadows represents an almost pure Leibnizian approach to the modeling of large complicated systems. The Forrester and Meadows model is, in effect, data independent. Now one can criticize the model on pure Leibnizian grounds, e.g. whether the internal theory and structure of the model are sound with respect to current economic and social theory, and some of the critics have chosen to do this. However, it would seem to us that more often than not the critics have chosen to offer a Lockean critique, i.e. that some other way, say using accurate statistical data, is a better way to build a sound forecast model of the world. While this is a legitimate method of criticism, to a large extent it only further exacerbates the differences between the two approaches and hence misses the real point. To us the real point is not whether the Forrester-Meadows approach is the correct Leibnizian approach, or whether there is a correct Lockean approach, but rather whether any Leibnizian or Lockean approach acting independently of the other could ever possibly be "correct." Forrester and Meadows seek to justify (guarantee?) their approach through the robustness and richness of their model, and their Lockean critics attempt to establish the validity of their approach through the priority and "regularity" of the statistical data to which they appeal. Perhaps if the debate proves anything, it raises the serious question as to whether an advanced society can continue to rely on purely Leibnizian or Lockean efforts for its planning. In order to really evaluate the relative merits of separate Leibnizian or Lockean Inquirers, it is necessary to go to a philosophy which incorporates both, such as the Kantian Inquirer.

The sense of Kantian inquiry can be rather quickly grasped through the following set of general characteristics.

(1) Truth is synthetic, i.e. the truth content of a system is not located in either its theoretical or its empirical components, but in ***both.*** A model of a system is a synthetic model in the sense that the truth of the mode1 is measured in terms of the model's ability (a) to associate every theoretical term of the model with some empirical referent and (b) to show that (how) underlying the collection of every empirical observation related to the phenomenon under investigation there is an associated theoretical referent.

(2) A corollary to (1) is that neither the data input sector nor the theory sector have priority over one another. Theories or general propositions are built up from data, and in this sense theories are dependent on data, but data cannot be collected without the prior presumption of some theory of data collection (i.e., a theory of "how to make observations," "what to observe," etc.), and in this sense data are dependent on theories. Theory and data are inseparable. In other words, Kantian IS require some coordinated image or plan of the system as a whole before any sector of the system can be worked on or function properly.

These hardly begin to exhaust all the features we identify with Kantian inquiry. A more complete description would read as follows: Kantian IS are the epitome of ***multimodel***, synthetic systems. On any problem, they will build at least two alternate representations or models of it. (If the alternate representations are complimentary, we have a Kantian IS; if they are antithetical, we have an Hegelian IS as described in the next section.) The representations are partly Leibnizian and partly Lockean, i.e., Kantian IS make explicit the *strong* interaction between scientific theory and data. They show that in order to collect some scientific data on a problem *a* posterior-i one always has had to presuppose the existence of some scientific theory a priori, no matter how implicit and informal that theory may be. Kantian IS presuppose at least two alternate scientific theories (this is their Liebnizian component) on any problem or phenomenon. From these alternate Leibnizian bases, they then build up at least two alternate Lockean fact nets. The hope is that out of these alternate fact nets or representations of a decision-maker's or client's problem, there will be one that is "best" for representing his problem. The defect of Leibnizian and Lockean IS is that they give only one view of the problem. Kantian IS attempt to give many explicit views. The guarantor of such systems is the degree of fit or match between the underlying theory (theoretical predictions) and the data collected under the presumption of that theory.

The reason why Kantian IS place such heavy emphasis on alternate models is that in dealing with problems like the nature of the future, the real problem is how to get as many perspectives on the nature of the problem as possible. Problems like the future are not problems that one can formulate and solve in the same way that one solves problems in arithmetic, i.e., via a single well-structured approach. There seems to be something fundamentally different about the class of problems to which forecasting problems belong. In dealing with the future, we are not dealing with the concrete realities of human existence, but, if only in part, with the hopes, the dreams, the plans, and the aspirations of men. Since different men rarely share the same aspirations, it seems that the best way to "analyze" aspirations is to compare as many of them against one another as we can. If the future is 99% aspiration or plan, it would seem that the best way to get a handle on the future is to draw forth explicitly as many *different* aspirations or plans for the *future* as possible. In short, we want to examine as many different alternate ***futures*** as we can.

In the field of technological forecasting, Normative Forecasting, Planning Programming Budgeting Systems (PPBS), and Cost-Effectiveness or Cost-Benefit Analyses are all examples of Kantian inquiry, although these are such low level Kantian inquirers as to be almost more Leibnizian in nature than Kantian. The Kantian element that these various approaches share is the fact that they are all concerned with alternate paths or methods of getting from a present state to a future state characterized by certain objectives, needs, or goals, or vice versa. When these various planning vehicles have failed, it has often been a problem of unclear or fuzzy objectives or poor compatability among data, models, and objectives. Furthermore these systems are usually applied with a questionable and implicit Leibnizian assumption that all benefits can be measured on a comparative dollar basis.

In recent years, there have been a number of Delphi studies which, in comparison to the techniques of the previous section more actively take on the characteristics of Kantian inquiry. These Delphis differ fundamentally from the original Delphis, which were strongly Lockean in orientation. The initial Delphis were characterized by a strong emphasis on the use of consensus by a group of "experts" as *the* means to coverage on a single model or position on some issue. In contrast, the explicit purpose of a Kantian Delphi is to elicit alternatives so that a comprehensive over-view of the issue can take place. In terms of communication processes, while a "consensus" or Lockean Delphi is better suited to setting up a communication structure among an already informed group that possess the same general core of knowledge, a Kantian or "contributary" Delphi attempts to design a structure which allows many "informed" individuals in different disciplines or specialties to contribute information or judgments to a problem area which is much broader in scope than the knowledge that any one of the individuals possesses. This type of Delphi has been applied to the conceptualization of such problems as (1) the definition of a structural model for material flows in the steel industry, (2) the examination of the current and the potential role of the mentally retarded in society, (3) the forecasting of the future characteristics of recreation and leisure, and (4) the examination of the past history of the internal combustion engine for a clue to significant events possibly effecting its future. While all of these Delphis had specific forecasting objectives, none of them could be achieved if all the parties to the Delphi were drawn from the same specialized interest group. The problems were broader than that which could be encompassed by any single discipline or mode of thinking. For example, the examination of the role of the mentally retarded in our society is neither the exclusive problem nor the sole province of any special group. Educators, psychiatrists, parents, and teachers all have different and valid perspectives to contribute to the definition of the "problem." Consensus on a single definition is not the goal, at least not in the initial stages, but rather the eliciting of many diverse points of view and potential aspects of the problem. In essence, the objective is establishing how to fit the pieces of a jigsaw together, and even determining if it is one or many puzzles. The problem of conceptualizing goals and objectives is not an explicit part of the three inquiry processes we have discussed so far.

Kantian inquiry is best suited to problems which are inherently ill-structured, i.e., the kinds of problems which are inherently difficult to formulate in pure Leibnizian or Lockean terms because the nature of the problem does not admit of a clear consensus or a simple analytic attack. On the other hand, the Kantian inquiry is not applicable to the kinds of problems which admit of a single clear formulation, because here the proliferation of alternate models may not only be costly but time consuming as well. Kantian inquiry may also overwhelm those who are used to "the single best model" approach to any problem. Of course this in itself is not necessarily bad if it helps to teach those who hold this belief that there are some kinds of problems for which there is no one best approach. Social problems inherently seem to be of this kind and thus call for a Kantian approach. The concept of "technology assessment" as a vehicle for determining the relationships between technology and social consequences would also seem to imply the necessity of at least a Kantian approach. Many efforts labeled assessments have proved to be inadequate because they were conducted as Leibnizian or Lockean Inquiries.

HEGELIAN OR DIALECTICAL IS

The idea of the Hegelian or Dialectical IS can be conveyed as follows.

(1) Truth is ***conflictual***, i.e. the truth content of a system is the result of a highly complicated process which depends on the existence of a *plan* and a diametrically opposed ***counterplan***. The plan and the counterplan represent strongly divergent and opposing conceptions of the whole system. The function of the plan and the counterplan is to engage each other in an unremitting debate over the "true" nature of the whole system, in order to draw forth a new plan that will hopefully reconcile (synthesize, encompass) the plan and the counterplan.

(2) A corollary to (I) is that by itself the data input sector is totally meaningless and only becomes meaningful, i.e. "information," by being coupled to the plan and the counterplan. Further, it is postulated that there is a particular input data set which can be shown to be consistent with both the plan and counterplan, i.e. by itself this data set supports neither naturally, but that there is an interpretation of the data such that it is consistent with both the plan and counterplan. It is also postulated that without both the plan and the counterplan the meaning of the data is incomplete, i.e. partial. Thus, under this system of inquiry, the plan and the counterplan, which constitute the theory sector, are prior to the input sector and indeed constitute opposing conceptions of the whole system. Finally, it is also assumed that on EVERY *issue of importance, there can be found or* ***constructed*** *a* plan and a counterplan, i.e. a dialectical debate *can be* formulated with respect ***to*** ANY issue. On any issue of importance there will be an intense division of opinion, feeling.

Hegelian or Dialectical IS are the epitome of ***conflictual***, synthetic systems. On any problem, they build at least IWO, ***completely*** antithetical, representations of it. Hegelian IS start with either the prior existence (identification) of or the creation of two strongly opposing (contrary) Leibnizian models of a problem. These opposing representations constitute the contrary underlying assemptions regarding the theoretical nature of the problem. Both of these Leibnizian representations are then applied to the same Lockean data set in order to demonstrate the crucial nature of the underlying theoretical assumptions, i.e. that the same data set can be used to support either theoretical model. The point is that data are ***not*** information; information is that ***which results from the*** interpretation of data. It is intended that out of a dialectical confrontation between opposing interpretations (e.g., the opposing "expert" views of a situation), the underlying assumptions of both Leibnizian models (or opposing policy experts) will be brought to the surface for conscious examination by the decision-maker who is dependent upon his experts for advice. It is also hoped that as a result of witnessing the dialectical confrontation between experts or models, the decision-maker will be in a better position to form his own view (i.e., build his own model or become his own expert) on the problem that is "creative synthesis" of the two opposing views. Whereas, in the Lockean IS the guarantor is agreement, in the Hegelian it is intense conflict-i.e., the presumption that conflict will expose the assumptions underlying an expert's point of view that are often obscured precisely ***because of*** the agreement between experts. Hegelian IS are best suited for studying "wickedly" ill-structured problems. These are the problems that, precisely because of their ill structure, will produce intense debate over the "true" nature of the problem. Conversely, they are extremely ill-suited for well-structured, clear-cut problems because here conflict may be a time-consuming nuisance.

Except for the Policy Delphi Concept of Turoff, the use of conflict as a methodology is conspicuously absent in the field of technological forecasting. In the "Policy Delphi" the communication process is designed to produce the best underlying pro or con arguments underlying various policy alternatives or resource allocation alternatives. In a non-Delphi mode (i.e., face-to-face) one of the most interesting applications can be found in the activity of corporate or strategic planning. In an important case study, Mason literally pioneered the development of what may be termed the Dialectical Inquiring System (DIS). The situation encountered by Mason was one in which the nature of the problem prevented traditional well-structured technical approaches to planning (i.e., Leibnizian and Lockean methods) from being used.

In the company situation studied by Mason, there were two strongly opposing groups of top executives who had almost completely contrary views about the fundamental nature and management of their organization. They were faced with a crucial decision concerning the future of their company. It was literally a life-and-death situation, since the decision would have strong repercussions throughout all of their company's activities. The two groups each offered fundamentally differing plans as to how to cope with the situation. Neither of the plans could be proved or "checked out" by performing any technical study, since each plan rested on a host of assumptions, many of them unstated, that could probably never be verified in their entirety even if time were available, which it wasn't. Indeed, if the executives wanted to be around in the future to check on how well their assumptions turned out, they had to make a decision in the present. It was at this point that the company agreed to let Mason try the DIS to see if it could help resolve the impasse and suggest a way out.

After careful study and extensive interviews with both sides, Mason assembled both groups of executives and made the following presentation to them. First, he laid out side by side on opposite halves of a display board what he took to be the underlying assumptions on which the two groups were divided. Thus, for every assumption of the one side there was an opposing assumption for the other side. Next, Mason took a typical set of characteristic operating data on the present state of the company (profit, rate of return on investment, etc.) and showed that every piece of data could be used to support either the plan or the counterplan, i.e. there was an interpretation of the data that was consistent with both plans. Hence, the real debate was never really over the data, as the executives had previously thought, but over the underlying assumptions. Finally, as a result of witnessing this, both groups of executives were asked if they, ***not*** Mason, could now formulate a new plan that encompassed their old plans. Fortunately in this case they could and because of the intense and heated debate that took place, both groups of executives felt that they had achieved a better examination of their proposed course of action than normally occurred in such situations.

Of course, it should be noted that such a procedure does not guarantee an optimal solution. But then, the DIS is most applicable for those situations in which the problem cannot be formulated in pure Leibnizian terms for which a unique optimal solution can be derived. DIS are most appropriate for precisely those situations in which there is no better tool to rely on than the opinions of opposing experts.

If the future is 99% opinion and assumption, or at least in those cases where it is, then the DIS may be the most appropriate methodology for the future's "prediction" and "assessment."

It is important to appreciate that the DIS and Policy Delphi's differ fundamentally from other techniques and procedures that make use of conflict. In particular, they differ greatly from an ordinary courtroom debate or adversary procedure. In an ordinary courtroom debate, both sides are free to introduce whatever supporting data and opposing arguments they wish. Thus, the two are often confounded. In a DIS, Hegelian Inquirer, or Policy Dephi, the opposing arguments are kept strictly apart from the data so that the crucial function of the opposing arguments can be explicitly demonstrated. This introduces an element of artificiality that real debates do not have but then it also introduces a strong element of structure and clarity that makes this use of conflict much more controlled and systematic. In essence, the Hegelian Inquiry process dictates a conceptual communication structure which relates the conflict to the data and the objectives. Under this conception of inquiry, conflict is no longer antithetical to Western science's preoccupation with objectivity; indeed, conflict actually serves objectivity in this case. This will perhaps be puzzling to those who have been brought up on the idea that objectivity is that upon which men agree and not upon which they disagree. While the Hegelian Inquirer does not always lead to a new agreement, i.e., a new plan, when it does, the agreement is likely to be stronger.

SINGERIAN-CHURCHMANIAN IS

Singerian IS are the most complicated of all the inquirers encountered thus far and hence the most difficult to describe fully. Nevertheless, we can still give a brief indication of their main features as follows:

> (I) Truth is pragmatic, i.e. the truth content of a system is relative to the overall goals and objectives of the inquiry. A model of a system is **teleological or** explicitly goal-oriented, in the sense that the truth of the model is measured with respect to its ability to define (articulate) certain systems objectives, to propose (create) several alternate means for securing these objectives, and finally, at the "end" of the inquiry, to specify new goals (discovered only as a result of the inquiry) that remain to be accomplished by some future inquiry. Singerian inquiry is thus in a very fundamental sense nonterminating, though it is response-oriented at any particular point **in** time, i.e. Singerian inquirers never give final answers to any question although at any point they seek to give a highly refined and specific response.
>
> (2) As a corollary to (I), Singerian IS are the most strongly coupled of all the inquirers. No single aspect of the system has any fundamental priority over any of the other aspects. The system forms an inseparable whole. Indeed, Singerian IS take holistic thinking so seriously that they constantly attempt to sweep in new variables and additional components to broaden their base of concern. For example, it is an explicit postulate of Singerian inquiry that the systems designer is a fundamental part of *the* system, and as a result he must be explicitly considered in the systems representation, i.e. as one of the systems components. The designer's psychology and sociology is inseparable from the system's physical representation.

Singerian inquirers are the epitome of synthetic multimodel, interdisciplinary systems. In effect, Singerian IS are meta-IS, i.e., they constitute a theory about all the other IS (Leibnizian, Lockean, Kantian, Hegelian). Singerian IS include all the previous IS as submodels in their design. Hence, Singerian inquiry is a theory about how to manage the application of all the other IS. In effect, Singerian inquiry has been illustrated throughout this paper in our descriptions of the inquirers, for example in our previous representations of the inquirers and in our discussions of which kinds of problems the inquirers are best-suited for studying. A different theory of inquiry would have described each of the inquirers differently.

Singerian IS contain some rather distinctive features which none of the other IS possess. One of their most distinctive features is that they speak almost exclusively in the language of commands, for example, "Take this model of the system as the 'true' model (or the true model within some error limits L)." The point is that all of the models, laws, and facts of science are only approximations. All of the "hard facts" and "firm laws" of science, no matter how "well-confirmed" they are, are only hypotheses, i.e. they are only "facts" and "laws" providing we are willing to accept or make certain strong assumptions about the nature of the reality underlying the measurement of the facts and the operation of the laws. The thing that serves to legitimize these assumptions is the command, in whichever form it is expressed, to take them seriously, e.g. "*Take* this is as the true model underlying the phenomenon in question so that with this model as a background we can do such and such experiments." Thus, for example, the Bohr model of the atom is not a "factually real description of the atom" but if we regard it as such-i.e. if we take it as "true"-then we can perform certain experiments and make certain theoretical predictions that we would be unable to do without the model. What Singerian inquirers do is to draw these hidden commands out of every system so that the analyst is hopefully in a better position to choose carefully the commands he wishes to postulate. Although it is beyond the scope of this paper, it can be shown how this notion leads to an interesting reconciliation between the scientist's world of facts (the language of "is") and the ethicist's world of values (the language of "ought"). In effect, Singerian inquiry shows how it is possible to sweep ethics into the design of every system. If a command underlies every system, it can be shown that behind every system is a set of ethical presuppositions.

Another distinctive feature is that Singerian IS greatly expand on the potential set of systems designers and users. In the extreme, the set is broadened to include all of mankind, since in an age of larger and larger systems nearly everyone is affected by or affects every other system. While the space is not available here to discuss the full implications of this proposition, it can be shown that every Singerian IS is dependent upon the future *for* its complete elucidation. If the set of potential users for which a system exists is broadened to include all of mankind, then this implies that every system must be designed to satisfy not only the objectives of the present but also the objectives of the future. Thus a Singerian theory of inquiry is explicitly concerned with the future and is by definition involved with the forecasting of the future. Singerian IS attempt to base their forecast of the future on the projections of as many diverse disciplines, professions, and types of personalities as possible.

The implication of Singerian inquiry for technological forecasting is that the supposed "fundamental *polarity of exploratory and* normative *technological* forecasting" completely breaks down. According to conventional wisdom, "exploratory *technological forecasting* starts from today's assured basis of knowledge and is oriented towards the future, while normative *technology* forecasting first assesses future goals, needs, desires, missions, etc. and works backward to the present."[1] However comforting this sounds, it ignores the basic Singerian point that every description of the present ("today's assured

[1] E. Jantsch, see references.

basis of knowledge") is based on some normative conception of the future (i.e. "future goals, needs, desires, missions, etc."). In Singerian terms, it is incredibly naive to take as "fundamental polarities" that which fundamentally interacts. Our normative plans for the future are idealized plans for expanding our knowledge of "what is known in the present." One of the reasons why man has always been interested in the future is because he has always been dissatisfied with that he has and knows in the present. Our plans for the future express what we wish the present were like.

As far as we know, Singerian inquiry is virtually absent from the field of technological forecasting and assessment. The closest related example we can give is Churchman and Ackoff's conception of Operations Research. Although OR in general is far removed from Singerian inquiry, Churchman and Ackoff have attempted to formulate a Singerian basis for the practice of OR.

The strength of Singerian inquiry is that it gives the broadest possible modeling of any inquirer on any problem. The weakness is the potentially prohibitive costs involved in such comprehensive modeling efforts. However, given the increased fear and concern with our environment, we may no longer have the choice but to pay the price. We may no longer be able to afford the continued "luxury" of building large-scale Leibnizian and Lockean technological models that are devoid of serious and explicit ethical considerations.

The Structure of Technological Forecasting and Assessment

The actual process of conducting a technological forecasting or assessment study can be said to concern itself with six basic types of information. These are:

(I) Feasible Technological Developments. Feasible usually means, in this context; technically feasible if the "required" resources are invested or available.

(2) Potential Applications. This is any possible application of the previous technological developments without regard necessarily to values-i.e. whether the application is "good" or "bad."

(3) Significant Applications. This is some subset of "all" potential applications or a transformation to some set which is of significance to the intent of the study.

(4) Potential Consequences. Any consequences, "good" or "bad," which may affect opinions of scenarios about the future, or our interpretation of the past.

(5) Policy or Resource *Allocation* Issues. The decision questions under examination or arising as a result of observing potential consequences.

(6) Potential *Resolutions* of Issues. The controls that can be imposed to effect the likelihood of various developments, applications, and consequences.

In essence, the above establishment of a classification scheme for this part of the discussion represents a Kantian exercise. Out of all possible classification schemes we have engaged in a Lockean process to arrive at a set of items which appears consistent with available data and which meets our objective of representing technological forecasting and assessment to the readership of this paper. If we were to claim this representation as the only "true" one, this would be imposing a Leibnizian view on the presentation of a structure. Further, to the extent that the above remarks and the views of the authors provide insight for the reader on the psychology and bias of the authors, then Singerian overtones have been introduced. Finally, if we managed to stir the reader to reflect on and strengthen his possible disagreements with us, we have stimulated a Hegelian process.

In general, the process of setting up a classification scheme which relates available or collectable data to objectives is Kantian. In the field of technological forecasting this is often referred to as "morphological analysis." As with other Kantian approaches, such as cost-effectiveness, there is always the danger of misinterpreting a Kantian truth as a Leibnizian one. With these caveats we may proceed to explore our proposed structure for technological forecasting.

The most general study possible would attempt, in principle, to enumerate all the items of "concern" falling in these categories and attempt to express the various interrelationships that existed among the items. However, in practice most technological forecasting and assessment studies usually focus attention on one of these categories and treat the others with various degrees of implicitness or explicitness.

It is quite common to find engineering forecasting studies which focus only on the first or second elements-developments and applications-with little reference to the other items. Those who look at the assessment element from the view of the social sciences usually focus on the consequences and policy issues-i.e., a policy analysis with only passing treatment of the technology. The economists and operations researchers tend to focus on applications and reduce consequences to examinations of dollar values, assuming consequences are identifiable in dollars.

One interesting observation that can be made explicitly from this structure is that the only evident distinction one can make between "classical" technological forecasting for organizational planning and the "new" technological assessment efforts is in how one defines the scope of the "Potential Consequences." In the former one is concerned with the effects on the organization (e.g., profits, markets, mission objectives, etc.), and, in the latter, the effects of concern are those on society (e.g., changes in lifestyle, job markets, education, pollution, etc.).

There are two considerations that considerably complicate this deceivingly simple structure for technological forecasting and assessment. The first is the problem of "enumeration"-how does one attempt to insure that all relevant pieces of information are included in the analysis. The morphological approach to this is the process of finding a model for classifying "all" items within a category into some finite set of subcategories which span the region of interest. In many cases these subcategories are tied to specific ranges of physical parameters such as velocity, frequency of radiation, weight, etc. While this approach works well when talking about developments or applications, immediate difficulties or disagreements arise when one moves into the area of consequences or policy and such questions arise as "What is an appropriate set of categories for expressing types of societies or attitudes of individuals?" In a sense, this paper itself is an attempt to describe a morphological set (the INQUIRY SYSTEMS) for technological forecasting and assessment techniques.

The second aspect of complication is in attempting to describe the interactions, interrelationships, causal effects, etc. among these various enumerated items. Our view of the future is dependent upon our view of the present and the resulting view of the past. There are no formal simplifications a priori, since the future as a system is transient and non-Markovian in nature. In fact, given ten events about the future there are about ten million relationships that could, in principle, be described among this small event set. A good many of the techniques in forecasting are merely attempts to define a less involved and approximate structure that is sufficient for picking out the significant interactions in any set of items. These approaches fall broadly into two general categories: matrix and network representations. Some of the names under which these two approaches are often disguised are cross impact, cross support, management matrices, relevance trees, decision networks or trees, and patterns.

When there exists a well understood structure that is fairly sparse with respect to interactions among the items, then a network or tree structure is often used. When the structure is not well understood or not sparse, various matrix methods are usually employed for defining the structure. If a good morphological set has been defined, the techniques for defining these relationships may be applied to the elements of the morphological representation, as opposed to the original information items. Since there is pragmatically an unlimited number of ways we can model the future, there exists a rich and growing literature on these morphological impact and/or relationship techniques. For the limited objectives of this discussion, a concept of the Inquiry Process associated with each step in the technological forecasting and assessment cycle should be sufficient to provide the reader with a perspective for evaluating these various techniques.

As illustrated in Fig. 2, the process of delineating and examining technological developments and applications can usually be handled by setting up a Leibnizian or Lockean Inquirer which utilizes various implicit or explicit future scenarios and representations of the past as the raw data input. The problem of determining "significant" applications and the resulting potential consequences dictates at least the use of a Lockean Inquirer and possibly a Kantian Inquirer. Especially when the problem is more of an assessment than a forecast, the Kantian approach should be mandatory for this

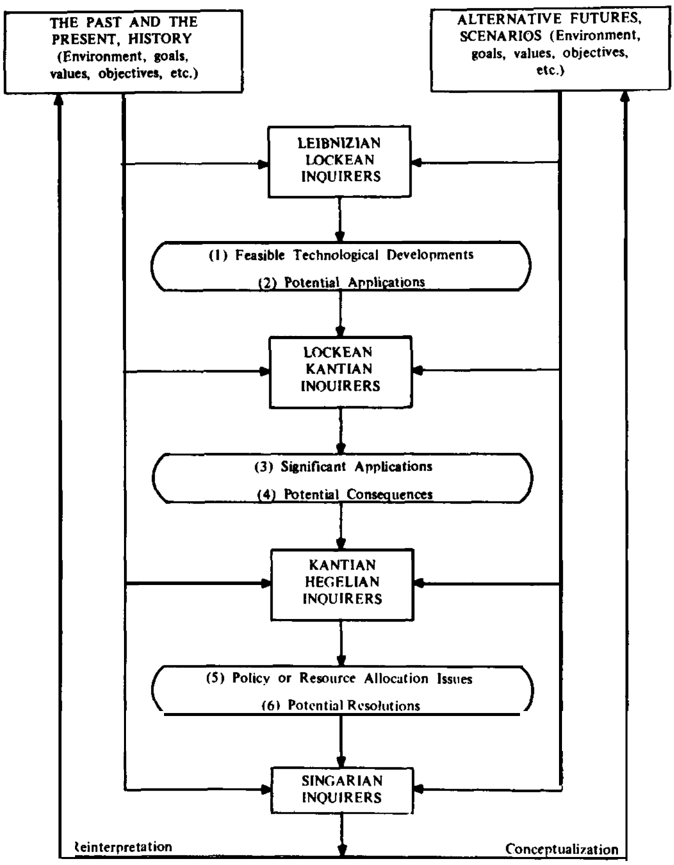

FIG. 2. The technological forecasting and assessment cycle.

part of the cycle. In the area of policy and resource allocation, either a Kantian or Hegelian process would seem to be appropriate. At this point most study efforts usually terminate. However, it is the view of the authors that the forecasting process is best viewed as a continuous cycle with two important feedback loops: the overall inquiry process should cause us both to examine the past for its possible reinterpretation, and the future for its conceptualization. The two of these taken together represent a Singarian process that ties all the other elements of the system together into a continuous reflective cyclic process.

When technology forecasting and assessment are viewed from this perspective, the process of studying the future becomes inseparable from the process of studying the past. A good forecaster should therefore be a good historian. Unfortunately, we find many examples of people and studies looking forward but not back, and vice versa.

Our view, then, of the relationships between technological forecasting and the various philosophies of inquiries can be summarized in Table 1.

Concluding Remarks, Technological Forecasting: Science and/or Mythology?

What separates science from mythology is not the subject matter of an inquiry but the approach. Something is a science if it can show (1) what that something needs to control, and (2) how to control it so that that something can study it in a controlled and systematic (i.e. scientific) way. In the field of technological forecasting we are just beginning to be aware of the first part, i.e. that the number of things we need to control (study) in order to make forecasts is indeed large. At the very minimum we need not only sweep in the things that the physical and social sciences study, but those that the humanities study as well, e.g. ethics.

In the end, it is the philosophical ability to be self-reflective that separates science from mythology. Self-reflection implies a realization that as much as our inquiry models describe and represent reality, they also describe and represent us, our psychology. Thus, for example, reflection points out that the mathematical type (the Leibnizian analyst) has an incessant need to reduce every problem to a mathematical one, even where it is not appropriate or efficient; the realist (Lockean) exclusively associates reality with facts or hard data even where the data is limited and confining; the idealist (Kantian) associates reality with possibilities even where they are not feasible; the pragmatist (Singerian) associates reality with the feasible, i.e. the do-able, even when it is not worth doing; and the *conflictual* (Hegelian) restricts reality to that which survives a strong debate even where a debate is not called for. in short, the difference between science and mythology is that the former, unlike the latter, attempts to study itself-to raise to consciousness its underlying premises and psychology.

Finally, reflection points out that the Sandburg anecdote quoted at the beginning of this paper about the circles of knowledge is the white man’s version of the situation. Nowadays we are beginning to wonder if perhaps the white man’s circle has always been smaller than the Indian’s, Mythology resides in the unexamined need to have one circle bigger than the other. Philosophy resides in the realization that neither circle can be known without the other. Science consists in making both an equal reality. In answer to the title of this paper: When one understands the philosophy underlying what he does, then he is engaged in science; if, however, he does not understand his philosophy, he is engaged in the practice of mythology.

TABLE I
Five Philosophical Approaches Underlying Technological Forecasting

Inquirer Approach	Characteristics of Problem for Which Approach Is Suited	Forecasting Techniques	Examples
Leibniz	Well-defined Analytical	Simulation, modeling Correlation analyses Substitution analyses	Simulation of an electronic system, transportation system, factory, etc.
Locke	Well-defined Experimental	Regression analyses Consensus Delphis Trend extrapolation	Forecasting of specific technical developments—i.e., a low-cost home computer terminal
Kant	Definable Defined objective Mixed analytical and experimental	Normative forecasting Gaming Coat-benefit analyses Scenarios Morphological analyses	Defining and evaluating the alternatives to meet a given objective
Hegel	Ill-defined Opposing objectives Intuitive or synthetic reasoning required	Policy Delphis and structured discussion systems	Developing an alternative decision out of conflicting ones
Singer	Ill-defined Unclear objective Multidisciplinary aspects Reflective reasoning required	NONE	Finding the forecasting methodology that applies to a particular problem

References

The references listed below are intended to provide the reader with general reviews, further background, and some specific examples of topics covered in the article. On the subject of Inquiring Systems the best place to seek further explanation would be:

1. C. West Churchman, The Design *of Inquiring* Systems, Basic Books, New York 197 1.

Those interested in attempts to construct formal mathematical representations of Inquiring Systems are directed to the following three articles:

2. Ian I. Mitroff, A communication model of dialectical inquiring systems-A strategy for strategic planning, Management Science 17, No. IO, B634–B648 (June 197 1).
3. Ian I. Mitroff and Frederick Betz, Dialectical decision theory: A *meta-theory* of decision making, Management Science, to be published.
4. Ian I. Mitroff, Epistemology as a basis for building a generalized model of general policy-sciences models, Management Science, special issue on The Philosophy of Science of Management Science, to be published.

The first book to organize into one source many of the fundamentals of technological forecasting and to attempt to provide a conceptual framework was:

5. Erich Jantsch, Technological Forecasting in Perspective, Organization for Economic Cooperation and Development, (OECD), 1967.

Some more recent books are:

6. Robert U. Ayres, Technological Forecasting and Long-Range Planning, McGraw Hill, New York (1969).
7. M. Cetron and C. Ralph, Industrial Applications *of* Technological Forecasting, Its Utilization in R *& D* Management, Interscience, New York (197 1).
8. Joseph Martino, Technological Forecasting for Decisionmaking, American Elsevier, New York (1972).

A short review of the Delphi method may be found in:

9. Murray, Turoff, Delphi and Its Potential Impact on Information Systems, Fall Joint Computer Conference Proceedings 1971, Vol. 39, AFIPS Press (American Federation of Information Processing).

A comprehensive review and analysis of Delphi methodology may be found in:

IO. H. Linstone and M. Turoff, Eds., Delphi and Its Application, to be published.

The journal of Technological Forecasting and Social Change (American Elsevier) is one of the best sources for articles of a specific nature on methodology. Examples pertaining to techniques mentioned in this paper include:

1 1. Edward B. Roberts, Exploratory and Normative Technological Forecasting: A Critical Appraisal 1, No. 2 (Fall 1969).
12. J. Martino, Correlation of Technological Trends 1, No. 4 (Spring 1970).
13. Murray Turoff, The Design *of a* Policy Delphi 2, No. 1 (1970).
14. J. Martino, Examples of Technological Trend Forecasting for Research and Development Planning 2, No. 3/4 (1970).
15. J. C. Fisher and R. H. Pry, A Simple Substitution Model of Technological Change 3, No. I (1971).
16. Murray Turoff, An *Alternative* Approach to *Cross* Impact Analysis 3, No. 2 (1972).

The Futures Journal *of Forecasting* and Planning (IPC Science and Technology Press Ltd., UK) is a good source for papers on the results from Technology Forecasting and Assessment Studies The magazine of the World Future Society (Washington, D. C.) provides a source of general review articles for the intelligent layman, e.g. the December I97 1 issue (Vol. 5, *No. 6)* was devoted to Technology Assessment.

Listed below are several other items related to the topics covered and which the authors recommend as reading material. Those by Mishan, Schon, and Schultz are rather down-to-earth discussions in the general areas of planning, assessment, and technology, and should effectively illustrate some of the differing philosophies and views possible on these subjects.

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