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NUCLEAR POWER AND SOME LESSONS OF TMI

The energy debate has heated up and there appears little likelihood of its cooling for a long time to come. The nuclear future—so confidently advanced by its proponents for the last two decades—has been dashed on the shoals of Three Mile Island (TMI).

NUCLEAR POWER ECONOMICS

But even before TMI, clouds had been gathering on the nuclear horizon, not the least of which was economics. Although nuclear proponents have continually been proclaiming its low cost and economic efficiency, the basis of their calculations have had a number of errors:

(1) Failure to foresee and account for escalating costs of mining and processing uranium ore due to the very nature of limited and nonrenewable resources. The easiest to reach and extract, the most concentrated resources are found and used up first. As each ton of ore is mined, the next one is more difficult to get out. As each grade of ore is used up, the next lower grade becomes harder to process. Not only does mining and processing become progressively more expensive, they consume a progressively larger fraction of the energy which the ultimate fuel will produce. Indeed, this increasing consumption of energy in production contributes to "the demand" for electricity on which the need for constructing more power plants allegedly depends. What part of the total "demand" is incestuous in this way? And how many GW of nuclear power would be obviated if this incestuous demand were removed?

(2) Failure to account adequately for the very great costs of safety and reliability. In the history of the nuclear power industry there have been countless accidents, most of them small, but a few substantial. As especially nuclear proponents claim, these are "learning experiences" that presumably lead to better designs, improved fabrication methods, more detailed monitoring, more frequent testing, more intense training of personnel, and more stringent and frequent inspection. All of these add to cost. They are not whimsical, unreasonable, bureaucratically-imposed costs, but legitimate costs of doing nuclear business.

(3) Failure to include in the economic calculations a range of costs that include:

a. Costs of liability insurance. The Price-Anderson Act not only limits overall liability for a nuclear accident to $560M, it passes on to the public a substantial fraction of even that low figure. Since the estimated bill for a meltdown that could have occured at TMI is $17B, if the burden of liability were removed from the public by repealing the Price-Anderson Act, the cost of liability insurance alone would make nuclear power economically nonviable. (In addition, see news item on costs of restarting TMI on p. 23).

b. Costs of waste disposal. The technology of storing radioactive waste products from nuclear reactors in such a way as not to endanger future generations for many millenia to come is not yet available. These materials have been accumulating in "temporary" storage areas with the

IN THIS ISSUE

even State governments are refusing to permit such storage dumps within their borders.

c. Costs of "decommissioning" exhausted nuclear plants. It is acknowledged by all that the lifetime of a nuclear reactor is approximately 35 years. After its useful life is over, what is to happen to the reactor? The term *decommissioning* may conjure up a vision of a flag-lowering ceremony accompanied by a few speeches, but the reality is that no procedures have been worked out to deal with the highly radioactive spent reactor. Furthermore, no firm estimates are available for the costs of decommissioning; hundreds of millions per reactor are involved.

Intellectually honest proponents of nuclear power owe the nation the professional responsibility to make realistic cost calculations that include all costs that should reasonably be charged to nuclear power, including others not mentioned here. It would be surprising if such calculations would not show the relative economic disadvantage of nuclear power.

No mention has been made here of breeder reactors. Even if the economics were right, there could be other reasons to decide against going to breeders. But let's assume those reasons are not compelling, that, for example, we will tolerate a curtailment of our civil liberties in the name of security against potential terrorists, and we want to decide only on the basis of economics. Most of the cost issues discussed still apply to the breeder, with a few others thrown in. Wouldn't it be reasonable to charge to nuclear power, for example, the R&D costs of the breeder and the increased cost of security to prevent theft of plutonium? Even if the breeder is admitted, the costs that should be reasonably charged to nuclear power are not likely to be substantially diminished.

Part of the difficulty in arriving at the truth about cost arises from the formulas by which electric utility revenue rates are calculated. There is an incentive for utility corporations to undertake those costs which are included in the rate base, and so will increase the rates they can charge, and to avoid those costs which are not. If two alternative ways exist to achieve a purpose, one more costly than the other, but influencing the rate base to a greater extent, the utility has an incentive to choose the costlier one. But what is more beneficial to the utility is not necessarily so for society.

NUCLEAR OPPONENTS: IGNORANT AND EMOTIONAL OR RATIONAL?

Nuclear proponents are often heard to claim that no one has been killed by nuclear power, even by the TMI accident; hence, it is safe. The corollary propounded is that if some people still oppose nuclear power on safety grounds, they are either ignorant (of the "no-fatalities" record), or they are reacting emotionally. Perhaps an analogy would Institute of Drug Abuse that, since 1964, 51 million Americans have tried marijuana without a single fatality from overdose or abuse! In view of this record, why is it that both users and sellers of marijuana face criminal penalties? There are probably a number of reasons, but perhaps the greatest one is the uncertainty concerning long-term consequences of marijuana use to health and life.

Even though neither users nor sellers of nuclear reactors face criminal penalties on that account, the certainty of the long-term consequences of nuclear power to health and life is far greater than that resulting from the use marijuana. Low-level radiation is no less deadly because disease and death occur after many years rather than suddenly. The probabilities of nuclear accidents resulting in large-scale loss of life and property are not as insignificant as the now-discredited 1975 Rasmussen Reactor Safety Study (WASH-1400) estimated. That is, people have a rational basis for their concern about the possible consequences of wide-scale deployment of nuclear reactors.

A FEW LESSONS FROM TMI

It is to be fervently hoped that, as nuclear proponents declare, the TMI accident taught lessons which will lead to improvements in reactor design and operating procedures, and in more effective regulatory control. And when the Kemeny Commission releases the report of its findings about the accident and presents its recommendations in late October, we will probably learn more lessons. But President Carter has already made it clear (in an interview with newspaper editors and news directors on August 10) that he will pay no attention to any lessons that are contrary to what he wants to hear. He will carry out the Report's recommendations, he said, "if they are at all practical."

But a number of lessons have already been learned through Congressional hearings, and through NRC documents and transcripts of meetings during the crucial hours and days following the accident.

(1) We learned, even more than we had from the NRC's withdrawal in January of its endorsement of the 1975 Reactor Safety Study, that probabilities of accidents reported in that study were greatly understated. The authors of that study had not conceived of the formation of a potentially explosive hydrogen bubble and so had not factored it into their calculations. Is it possible they missed some other constellations of events which renders their calculations even more suspect? (It would appear, incidentally, that no responsible scientist would continue to put forth the discredited figures that the chances of injury by a nuclear accident are "about the same as being hit by a falling meteor," but that is exacly what Edward Teller did in a double page ad in the Wall Street Journal of July 31, 1979.)

(2) We learned that, for at least the first 48 hours after

(Continued on page 23)

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# of Engineering and Its Implications for Management

Roland Schinzinger

We live in a world in which little appears to be stable but the very presence of change itself. Engineers must invariably be counted among the agents of change, if only because the size and complexity of their projects or the sheer number of products manufactured affect our natural and social ecosystems. Engineers have the particular talent of accomplishing a task with only partial knowledge of nature's laws and society's whims, but this attribute also imposes grave responsibilities, particularly when the side effects of their efforts are difficult to foresee. Thus, whenever further exploration must be bypassed for the sake of moving ahead on a project, engineers should proceed as if they were conducting a critical experiment involving human beings.

Can engineers be expected to perform responsibly as experimenters, as agents of change? And what are the implications for managers of engineers? In attempting to answer these questions it will be necessary to examine the milieu of the engineering workplace, the nature of the "experiment," and finally the role of management in nurturing "responsibility."

THE ENGINEER AS AN EMPLOYEE

Not long ago engineers were hailed as pioneers who tamed the forces of nature and exploited its resources for the benefit of mankind. Today, engineers continue to create ever more amazing marvels, but it is a time when technology is seen as capable of meeting many of our physical needs and the public's attention has shifted to the harmful side effects of technological growth and innovation. This change in public attitude has been accompanied by a change in the position of most engineers. Very few (about five percent) are independent entrepreneurs. Most work in large organizations where they may be given little room for autonomy, particularly where division and specialization of labor is practiced to a high degree. Nevertheless, engineers are indispensable contributors to mass production or the creation of immense projects. When speaking of engineers hereafter it is mostly in reference to the employed engineers.

The typical employer of engineers operates in an environment characterized by enormous concentration of economic power, not much real competition, and a system where prices, production, and relationship between capital and labor are largely administered. The engineer is expected to be loyal to absentee owners who may sell their in-

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decline of the independent professional.[1] The large organization in private industry and government has often taken on a life of its own, creating its own set of written and unwritten rules, such as the ones that make managers, as members of a caste, often display more loyalty to each other than to the remote owner or client.[2] Perhaps there lies a lesson therein to be learned by the engineer. Incidentally, the preponderance of the engineering managers is drawn from the ranks of engineers. For purposes of distinction we shall label as managers those who are responsible for administering others from well-defined short term goals.

At times the engineer is closer to the client than to the owner of the enterprise or its ultimate boss. It is in such a setting that employed engineers face the dilemma of having to please more than one client: the employer, the customer, and —indirectly—the public at large. This multiple responsibility, it has been observed, could tax any double agent.

THE ENGINEER'S TASKS AND EXPERIMENTATION

Engineers are called upon to prepare proposals and to sell, to develop and to design, to build or to manufacture, and ultimately to test. A particular job may include the entire sequence, or only a subset of these activities. The object of these activities may be a reservoir and aqueduct system, it may be a new line of aircraft, of special purpose computers, or of nuclear reactors. It may be a mass-produced hair dyrer. Hereafter, for convenience, we will simply refer to the engineers' creations as their products.

The introduction of many products, including the above mentioned, may be viewed as an experiment on a societal scale. In each case the ultimate outcome is uncertain; it is not even known what the set of possible outcomes may be. The reservoir may do damage to the region's social fabric or to its ecosystem. It may not even serve the intended purpose if the dam leaks or breaks. The aqueduct may bring about a population explosion in a region where it is the only source of water, creating dependency and vulnerability without adequate safeguards. The aircraft may become a status symbol which bankrupts its ultimate owners. The special purpose computer may find its main application in the indentification and surveillance of dissidents by totalitarian regimes. The nuclear reactor, a scaled-up version of a successful smaller model, may exhibit unexpected symptoms which endanger the surrounding population and necessitate an untimely and permanent shutdown at great cost to owner and consumer alike. The hair dryer may expose the unwary to asbestos from the insulation in its barrel.

Such outcomes are not the rule, but they do occur with sufficient frequency and with such cost in health and dollars that the public has become rightfully concerned.

It may be said that engineers should not be held accountable, any more than a manufacturer of kitchen knives can be made responsible for stabbings in the home.

But there is a difference, surely. By and large the public is not privy to the workings of many engineering products, particularly the large, complex ones. Our five senses are inadequate to perceive many of the danger signals, and experts must be relied upon to sound a warning. Where are these experts, the engineers? Possibly on a new project, bringing out a new product, too preoccupied to monitor earlier creations. In other words: the experiments are continuing on their own, but without direct observers and without control.

Two remedies are often proposed: (1) Trust technology to produce a remedy, or—if that does not seem promising—then (2) pass laws which will prescribe safeguards against any undesirable effects.

Neither is entirely satisfactory to me. First, they do not take into account the time delay which invariably occurs until remedial action is instituted and during which the damage continues to mount. Secondly, they do not sufficiently address the underlying problem: the tendency to shift the burden to another party (to find a remedy) when the real need is for defensive engineering at the outset[3,4], a concept akin to preventive health care. After a failure has occurred, certainly a variety of remedies may be appropriate. But it is questionable whether a crisis-driven reaction is the proper one, as typified by the following example. Shortly after the Santa Barbara oil spill the editor of a Southern California newspaper[5] took issue with a widely circulated proposal to protest Union Oil's complicity by destruction of this company's credit cards. The editor proposed instead that "while the oil company must bear its full share of responsibility for the damage, the real target for ire and action in this unhappy affair should be the U.S. Department of the Interior, which failed to require drilling safeguards as effective as those of the State of California."

We should now ask ourselves: Who are the experts who will be called upon to help draw up the standards? If, as is likely, it is the same engineers and experts who work for the oil drillers, why did they not take proper precautions to begin with? Must all of our actions be guided by laws? Will we never act unilaterally, when doing so may give someone else a competitive edge?

The answer, unfortunately, is "yes" in most cases, as reflected by past practice. Thus there seems to be no recourse but to enact even more laws, something industry generally decries but implicitly invites—and with every new law come new loopholes which provide legitimacy to unwise courses of action. Laws do no prevent abuse as much as they provide some modicum of support to those who would remain honest. The only other avenue would appear to be a refusal by those in the know to be drawn into improper experiments. What then is a proper experiment, and what does it take to carry it out?

A PROPER EXPERIMENT

An experiment conducted in a societal setting usually involves one or more "treatments" which are administered to a set of persons or situations selected at random from a specified population. The experiments of concern to us here do not involve such careful selection of subjects, except in demonstration projects of smaller scale. The typical experiment instead is conducted on a large scale with few controls and little preparation. Nevertheless, it is appropriate to speak of experiments because of the uncertainties associated with the outcomes of purposefully instituted procedures or products. Furthermore, these are experiments on human subjects—a situation which would demand special attention.

For our purposes one of the main features of a proper experiment is follow-up by means of continuing observation and monitoring of the product, even after it has left the factory floor or showroom, coupled with appropriate action if during the course of this follow-up it is found that the product produces undesirable fallout. The engineer as experimenter may have to terminate the experiment or at least change its course.

Who is to be the monitor? Many engineers are likely to find reasons why they themselves are not the proper monitors: "In a large organization there is surely someone else designated to take care of it," or "Let the customer shoulder the burden," or "That gets out of my field—I feel uncomfortable in the public arena," or "I ought to do it, but there is no time or budget for it."

Whether it be lack of opportunity, rationalization, or self-deception on the part of the engineer, it is left to management to provide designated monitors. It is up to management to assure free flow of information among the personnel in related sections, even if managers must give up their positions at the nub of the information exchange. Consider what happened in the Grand Teton dam episode.[6] Design engineers did not visit the construction site sufficiently frequently to assure themselves that the actual soil conditions matched those they had expected. The severe problems associated with the futile attempts to effectively plug potential leaks with grouting could therefore never be fully appreciated by them. As the dam was filled, all experimental caution was cast aside and a filling rate far above normal was allowed to satisfy the contractor's deadlines. Instrument readings indicating seepage were taken, but they were sent routinely to headquarters where they arrived the day after the dam had broken.

The Teton dam case is a classical example of the lack of direct communications between separate departments (between the designers and the builders, between the testers and the operators). What mechanism for information exchange existed probably involved the usual up-the-line communication flow on one side and down-the-line on the other. Of the original message very little is transferred by this process as the message is first filtered on its way up and then embellished with related but unessential content on the way down. Wilmotte[7] ascribes to this typical process another attribute: the think-positve syndrome which arises from the need of employees at one level having to sell their competence to their superiors at the next level and so on, "each seeking recognition and avoiding being the bearer of bad news . . . ." Wilmotte continues: "The syndrome inevitably tends to obscure uncertainties until they become visible as deficiencies, to let negative things develop until

undermine attempts at measuring performance, in sum, to postpone the discovery of trouble."

Surely it is a challenging task for management to correct such situations. The project approach is but one step in the right direction. But a much more formidable task awaits management when an engineer does indeed monitor the experiment or becomes an unexpected witness, observes danger signals, and recommends action which run counter to mangagement's short run objectives.

HOW TO ALTER THE COURSE OF AN EXPERIMENT

By plan or not, engineers frequently find themselves in a position where they clearly see the need to redirect an experiment, which is to say redesign a product, recommend changes in its use, or improve its quality through changes in manufacture and quality control. It is in connection with such alterations of management's original plans that manager of engineers must show a proper regard for the nature of engineering.

The engineers' codes require engineers to hold the public welfare paramount. Engineers are expected to perfect their skills, to use their best judgment, and to be truthful. This is what professionalism is all about—with one important addendum: obligations should not be imposed without there also being provisions for the right to act in accord with professional judgment and, ultimately, conscience.

Engineering codes do not address this issue, and in this respect they are deficient, although it may be argued that professional freedom is more a matter of guidelines for employers than for employed engineers.

Let us look at some cases and see what happened to the engineers involved when they attempted to bring about changes. Three BART engineers were concerned about inadequate safety features and quality control on their new rail system. They reported their findings to their supervisors, only to be rebuffed. When they eventually went to a member of the board of directors, management accused them of going public and fired them.[8] A civil engineer on a highway job in the Andes reported to his superiors, and eventually to government officials, about the steep cuts into the mountainsides. His firm dismissed him.[9] A welder was dismissed from his position as inspector because he insisted on high quality work in nuclear plant construction.[10] An aircraft designer reported the possible consequences of a new cargo door design which can lead to sudden decompression. He was overruled, but kept his job.[11]

A BART train eventually overshot the terminal and went off the track. The train control system had to be modified at great cost. The highway in the Andes experienced massive slides. Poor workmanship in nuclear power plants has recently exacted its toll at Three Mile Island. Most of the engineers involved in these cases not only lost their jobs, but found themselves blackballed as well. One of the airplanes with the questionable cargo door crashed precisely for the reason foreseen and took 346 persons to their deaths. In the end all of the employers faced huge losses. It is not for ethical reasons alone then that a case can be

Unlike the unionized blue collar workers, engineers do not deal from positions of strength vis-a-vis their employers. Only a few invaluable, top ranking engineers with an organization, perhaps already indentified with mangagement, dare stand on their principles without inviting possible reprisal, either immediately or protractedly through years of delayed promotions. Even where management would not be inclined to retaliate, engineers feel an implied threat.

Avenues for voicing concern must be provided within the organization. The introduction of an ombudsperson who can listen to all concerns and who can intercede on an employee's behalf at any level is one approach. Another one is an in-house panel of engineers who provide a fact sounding-board for technical dissent. In both cases, management should be obligated to state precisely how and under what circumstances the ombudsperson's or the panel's recommendations will be followed or rejected.

Engineers should not necessarily rely solely on such in-house provisions. If no satisfaction is found internally, engineers should be allowed to report to a professional society and to a regulatory agency. Whistle-blowing is generally a measure of last resort with most engineers because, as stated earlier, entering the public eye is not their natural inclination.

How is increased freedom for the engineer going to affect the mangagers of engineers? Is their authority going to be compromised? Only if their decisions are repeatedly shown to hinge on narrow, short-term goals will their wisdom be questioned. Managers, after all, are partners in the long range experiments on which they are embarked with their engineers.

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"Cogeneration" Solar Power System

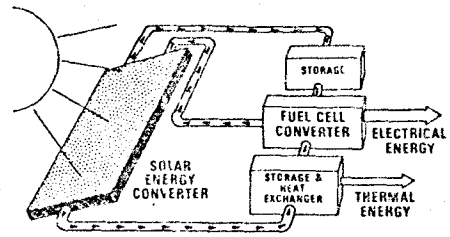
Texas Instruments (TI) has been working under a Department of Energy (DOE) contract to develop a solar electric power system suitable for both home and commercial use, and has achieved a working system that converts sunlight to electricity with an efficiency of seven percent. Ten percent seems to be within reach, but the design goal is 13 percent.

Rather than a solid silicon crystal, the photovoltaic converter consists of tiny 100-200 mm diameter silicon crystal spheres bonded onto a substrate. Up to 95 percent of the silicon is active in the conversion process compared to a maximum of about 20 percent in the conventional single crystal solar cell. The entire structure is immersed in an electrolyte (hydrogen iodide or hydrobromic acid).

But the direct photovoltaic conversion is only part of a closed-loop system which operates as follows. The electricity generated by the photovoltaic conversion decomposes the electrolyte, yielding hydrogen. This is passed into a fuel cell for which it becomes the fuel, generating electricity—from a few hundred to a few thousand watts. The waste heat from the fuel cell goes to a heat exchanger where it is used to produce hot water or hot air for space heating. Everything is recycled back to the collector to reform the electrolyte. A schematic diagram is shown.

The entire system yields both electricity and hot water and air. The efficiency is, therefore, about twice the value for electrical conversion alone.

CLOSED LOOP SOLAR ENERGY CONVERSION SYSTEM



NEW DIMENSIONS OF APPROPRIATE TECHNOLOGY

Symposium Announcement

A two-day symposium, 10-11 November 1979, sponsored by the International Association for the Advancement of Appropriate Technology for Developing Countries (IAAATDC) will be held at MIT. There will be papers and reports by people engaged in the definition, development, transfer, or use of appropriate technology in the following general areas.

- Education
- Health and nutrition
- Agriculture and rural development
- Commerce and Industry
- Information (communication) sciences

The IAAATDC was organized in 1978 with the assistance of the American Association for the Advancement of Science. Its aim is to promote the socioeconomic advancement of developing countries through a systematic application of science and technology that is appropriate to country-specific developmental problems, needs and conditions. It publishes a quarterly journal, APPROTECH.

Further information about IAAATDC and the Symposium can be obtained from the present headquarters at 603 E. Madison Street, University of Michigan, Ann Arbor, MI 48109

Conference Announcement: NTC 79

The National Telecommunications Conference (NTC) will be held for the first time in the Nation's Capitol, November 27-29, 1979, at the Shoreham Americana Hotel.

The conference will highlight the policy, systems and technology that will shape the future of telecommunications. The program features 48 technical sessions, stimulating panel discussions, and exhibits of the latest equipment. This forum will project a picture of a future largely dependent on how well we harness the many faceted, exploding technology tat produces new telecommunications services daily while rendering existing ones obsolete. The potential futures for common carrier technologies, markets and regulations, the impact of the 1979 General World Administrative Radio Conference and the impact of emgerging technologies such as optical communications will be thoroughly discussed.

Introduction

The use of mathematical and computer-implemented models for study of socioeconomic system dynamics has become increasingly popular in recent years. In their enthusiasm for these methods, many investigators have ignored, or seriously underestimated, certain intricate technical problems which place stringent limitations on the validity of model-based predictions. This article is intended to provide a brief discussion of these matters. For clarity it is perhaps best to begin with a few simple definitions.

A *formal* or *mathematical* model will be taken to denote an expression, written in a logically precise notation, amenable to evaluation either by computer or by analytic mathematical techniques, and which may be interpreted (in a vernacular) as a metaphor for a process believed (or hypothesized) to occur.

A formal *socioeconometric* model will be taken to denote a formal model whose allegorical interpretation encompasses both econometric (e.g., supply/demand→ price) and sociometric (e.g., logistic population growth) concepts.

Contemporary applied mathematics literature abounds with such models. Two examples widely reported in the popular press are the Brookings Econometric Model [1] and the Forrester World Model [2]. The former is representative of detailed, multifactor econometric models which are used by government and private sector economists to anticipate and adjust for economic trends, while the latter is intended to represent broad social phenomena (population growth, resource depletion, etc.) in a simple heuristic fashion suitable for use as a didactic tool. These specific models are mentioned here only for convenient reference, to give the uniniated an orientation, and because each is representative of a widely espoused approach to socioeconometric modeling. The commentary will be sufficiently general to encompass a broad class of formal models. It should also be mentioned that the term *prediction* will here be used in a broad sense to include both temporal prediction (i.e., so-called "forecasting") and policy or structural prediction (i.e., the differential effects of changes in model parameter values, inputs, or structure.)

The two examples cited above differ in numerous respects which provide some insight into the associated problems. The Brookings model is vastly larger and more elaborate as judged by the number of equations and computer resource needed for their solution. The basic structure is that of a system of several hundred difference equations, some of which involve nonlinear expressions. The unit time increment is three months, a consequence of a data base composed in part of quarterly econometric time series. The equations are constrained by methodologic considerations to a structure which lacks global validity (i.e., the equations are not qualitatively correct under socioeconomic conditions which differ more than slightly from the reference standard). Some sociometric variables are incorporated, but the primary emphasis is econometric. The Forrester model appears almost trivial by this standard. Its structure is essentially that of an autonomous system of five first-order nonlinear ordinary differential equations. More emphasis has been placed on sociometric variables (e.g., population size) than on econometrics, although highly aggregated economic variables do significantly influence model behavior. Methodologically, a more flexible approach is taken which, in practice, achieves something like a trade-off of component number for heuristics. That is, model equations may take any computer implementable form (presumably supported by rational argument), but the level of aggregation must be kept very high to minimize parameter estimation problems and to avoid serious mathematical difficulties (discussed at a later point). Simply the freedom to specify more generally descriptive equations does not, of course, provide any guarantee of model validity, and experience with models of this type indicates very limited success at predicting the past.

Deceptively simple nonlinear models can, however, exhibit dyamical response features of enormous complexity. Thus, assessments of model complexity must in general consider both structural and behavorial aspects. The Brookings model is intended to provide quantitative, short-term (months) predictions of economic trends in response to small changes in fiscal/monetary policy. The Forrester model is intended to predict comparatively gross, qualitative, long-term (decades) socioeconomic trends as a consequence of broad (hypothetical) alternative societal characteristics (e.g., assumptions regarding fertility rate and resource utilization.) While much modern interest in the subject has obviously been stimulated by the rapid development of computer technology and further encouraged by academic acclaim accorded econometric research, it should be noted that historical antecedents include the demographic models of Galton and Watson, logistic growth models of Malthus and Verhulst, and the comparatively recent species-interaction models of Lotka and Volterra.

Somewhat paradoxically, a problem that confronts any attempt at serious criticism of such models and techniques is that many flaws are glaringly self-evident; thus it may be difficult to know where best to begin. The present com-

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mathematical discoveries which pose very serious questions for model validity. The virtually total inadequacy of any known methods to contend with the obvious complexity of socioeconomic systems should, however, be judged in relation to considerations of social utility and *de facto* (alternative) methods of analysis. Thus, as a hypothetical example, if an econometric model could prescribe Federal Reserve policy so as to achieve greater restraint of both inflation and unemployment than expected to occur by more traditional policy setting methods, the social utility of the model could offset criticism of technical details. The situation has obvious similarities to the development of scientific theories (e.g., Newtonian gravitation and the point mass approximation) with the distinction that most models in physics are both more elegantly derived and more amenable to experimental verification. The latter point raises a further difficulty with respect to evaluation of our hypothetical econometric model. Any claim that it yields better policy cannot be tested experimentally; it may only be judged by simulation and inference. Further complications arise by admitting the fact that a generally superior model (or technique) may not be superior under all conditions; moreover, there may be no analytic methods by which the circumstances favoring one model over another can be determined *a priori.* If such specification were feasible, it might then, of course, be possible to obtain improved performance with a hybrid model.

In addition to the rational aspects of model validity, which will be discussed further subsequently, there are a number of suprarational factors which can have a substantial effect on the perception of the merits of a model. At a trivial level it is apparent that simply the use of sophisticated mathematical concepts and computer programs can, of itself, either impress or disaffect critics depending upon their personal attitudes. The wide availability of computer software packages designed to enable the relative neophyte to obtain numerical solutions to complicated mathematical problems has had a negative impact to the extent that it has encouraged sometimes quite elaborate modeling efforts by groups lacking the sophistication to understand the limitations of their own work. A further factor affecting perceptions which will here be classified as suprarational is the characteristic of formal models to reveal explicit and (to a lesser extent) implicit assumptions and thus lose credibility. While equally simplistic assumptions may, in fact, underlie both formal models and the personal judgments of more traditional authorities, model assumptions are in general more easily specified and thus criticized. Given the computer resources, simulation can be used to expose model inadequacies in a devastating fashion hardly possible with more subjective arguments. On the other hand, the nebulous mental processes which give rise to so-called intuition can undoubtedly be of great value; formal models have yet to be devised which can adapt to complicated change in circumstances. Moreover, as computer-implemented models grow in complexity, their analysis and criticism becomes a serve to conceal serious model flaws from even its most knowledgeable users. These and related issues, which are highly subjective, will not be considered here.

The representation of a physical or societal process in an axiomatic system (language) requires, of itself, an initial stage of abstraction whose nature is determined, in part, by the character of the language employed. For example, the contention that a spring-mass system is isomorphic to a linear second-order differential equation involves tacit reference to an idealization, Hooke's Law and Newtonian mechanics, and certain practical experience with mechanical oscillations. Broader experience, e.g., somewhat larger oscillations or the extremes of quantum mechanical and relativistic phenomena, would lead to different postulates. It is self-evident that the dynamics of socioeconomic systems are determined by an enormous number of mutually interacting components. Even at a comparatively gross level of aggregation which ignores the fundamental fact that societal systems are composed of individual human beings, it must be acknowledged that the dynamics of such simple econometric measures as the GNP are determined by economic subsector interactions. For a credible mechanistic model these relationships must be explicitly represented. Alternative methodologies which involve multivariate time series analysis, without regard to underlying system mechanics, can be (and are) used for short-term demographic and econometric forecasting but, lacking an explicit structural analogy, are of little value for other purposes. The analysis given here will be restricted to models composed of nonlinear ordinary differential equations. Static models provide no insight into system dynamics. Linear models suffer from both structural artifice and performance limitations but may, of course, be justified in study of variational problems. Short-range economic policy matters can be viewed in such terms, but will not be considered here. Finite difference equations provide an attractive alternative to ODE models both from the standpoint that econometric time series have a discrete character (e.g., daily stock market averages, weekly, monthly, or quarterly financial reports, etc.) and the finite differencing which occurs in digital computer implementation. The performance of difference equation models may be no less complex than analogous ODE's; thus the problems analyzed below in the context of ODE models cannot in general be avoided by this approach. The relative merits of these alternative formulations and the conditions under which they become mutually approximate will not be discussed here. In specific models stochastic components may be utilized to approximate complex social interactions. This further complication also need not be considered, in as much as it would not alter the conclusions reached.

In addition to the appearance of a structural analogy, it is necessary for a credible model to exhibit strong behavioral similarities to the modeled system under all appropriate conditions subject to test. As alluded to above, general dynamical tests of socioeconometric models are not feasible; thus in practice the testing is usually limited to

comparisons between simulated and observed historical demographic and econometric time series. Reliance on such measures is suspect, particularly when the same data has also been used in model formulation and parameter estimation. Assuming that it has nonetheless been possible to develop and validate a credible model, a final objective (in fact most often the *raison d'être*) is to demonstrate the model's utility as a predictive tool. This can become a problem of truly extraordinary mathematical and philosophical complexity. In order for model predictions to be useful they must be both *nontrivial* and *insensitive* to all model structural perturbations which are of a minor nature in comparison with the extent of the simplifying assumptions entailed in model formulation. These perturbations must be taken to include not only uncertainities in model parameter estimates but also small, arbitrary changes in the model equations (i.e., structure.) To restate this important point, the prediction obtained from a specific model is only useful to the extent that it can be shown not to depend in any critical way on the myriad assumptions which are (unavoidably) involved in model formulation. Clearly, the "nontrivial" aspect of prediction requires, in part, that the extrapolations *not* be limited to a small domain in which continuity provides a significant constraint to model behavior.

Analysis

A reasonable, general autonomous ODE model for multicomponent competition for a limited resource is the system of equations:

$$dx_i/dt = x_i M_i(X), \qquad i = 1, \ldots, n \tag{1}$$

where $X = (x_1, x_2, \ldots, x_n)$ the "state vector" with $x_i \geqslant 0$ in accord with the "population size" model interpretation, i.e., the state space

$$R^n_+ := \{X \in R^n \mid X = (x_1, x_2, \ldots, x_n), x_i \geqslant 0\}.$$

$M_i : R^n_+ \to R$ such that:

i) $M_i(X)$ is C^∞;
ii) $\partial M_i(X)/\partial x_j < 0$, for $x_i \neq 0$ all i, j;
iii) $M_i(X) < 0$, if $\|X\| > k$ all i, k a finite positive constant.

Stipulation i) guarantees "smooth" infinitely differentiable behavior, ii) represents competition and can be interpreted as "crowding inhibits growth," iii) can be interpreted as "finite resource can only support finite population." Clearly the continuum approximation requires that only large populations be considered. For notational simplicity these are normalized in the examples which follow.

Such models have found application in the study of ecological competitive species interactions [3] and, though differing in structural detail from popular econometric equations, could also be interpreted as representing economic subsector competition for limited financial or material resources. For the purposes of the present commentary it represents an arbitrary but entirely appropriate example by which to demonstrate some profoundly disturbing aspects of the model prediction problem. The analysis which follows is due to Smale [4] and shows that multicomponent models of the form (1) may be devised which possess any dynamical behavior when the number of interacting components exceeds four. His analysis, rooted in differential topology, is accomplished by evaluation of the dynamical behavior of three examples, satisfying the requirements above, but conjured so as to demonstrate his conclusion.

Example 1

Let $M_i(X) = 1 - \Sigma_{j=1}^n x_j$, $i = 1, \ldots, n$. In this case the boundary (some $x_i = 0$) is invariant under the flow, and all other solutions tend ($t \to \infty$) to the stationary set $\Delta_1 = \{X \in R^n_+ | \Sigma x_i = 1\}$. This degenerate case has little physical appeal but provides an introduction to Example 2, which remedies the defect at the cost of some intricacy (the notion being to introduce a dynamic on Δ_1.)

Example 2

Define:

$\Delta_0 = \{X \in R^n \mid \Sigma x_i = 0\}$
$I_n = (1,1,\ldots,1) \in R^n_+$
$\beta : R \to R$ a C^∞ function $= 1$ in a neighborhood of 1 and $\beta(z) = 0$ if $z \leqslant 1/2$ or $z \geqslant 3/2$
$H : R^n_+ \to \Delta_0$, $H(X) = (1/n)I_n - (X/\Sigma x_i)$
$m_i(X) = (1/x_i)\, \beta\, (\Sigma x_i)\, (\Pi_{j=1}^n x_j) h_i(X)$.

Then by perturbation of Example 1:

$$dx_i/dt = x_i\,(M_i + \eta m_i) = x_i N_i(X).$$

For small positive η the model requirements are satisfied. The various terms composing the m_i are contrived so as to limit the domain over which the perturbation is nonzero. As for Example 1, nonboundary solutions tend ($t \to \infty$) to Δ_1. On Δ_1 the $M_i = 0$, and the flow is determined by the $x_i \eta m_i$, or up to a scalar equivalence by H restricted to Δ_1. On Δ_1 the (linear) differential equation $dX/dt = H(X)$ has $(1/n)I_n$ as a global sink. Thus every nonboundary solution of Example 2 tends to $(1/n)I_n \in R^n_+$ as $t \to \infty$. Example 3 simply demonstrates that Example 2 can be modified by changes in H to produce arbitrary behavior without violating the *a priori* model stipulations.

Example 3

Let

$H^0 : \Delta_1 \to \Delta_0$ be any C^∞ map
$H : R^n_+ \to \Delta_0$ any C^∞ map which agrees with H^0 on Δ_1.

Example 3 is then Example 2 with the substitution for H. Up to a scalar factor, the dynamic ($t \to \infty$) is given by $dX/dt = H^0(X)$ on Δ_1. Inasmuch as H^0 is arbitrary, this can be any dynamic. By the constraint relation Δ_1 is of dimension one less than the model state space. Thus the dynamical behavior can be made equivalent to any C^∞, $n-1$ dimensional system. For example, if $n = 3$, then a system with a limit cycle can be put on Δ_1. If $n \geqslant 5$, then Δ_1 will accept

systems of great dynamical complexity, see [5] for examples and discussion.

It should be noted that fundamental distinctions exist between system transients and the autonomous dynamical behavior reached in the limit as $t \to \infty$. Models may be used in a fashion such that this limiting dynamic is not observed. In the examples just considered this would correspond to a situation in which $\eta \|m\| / \|M\| \ll 1$, the initial condition is far from Δ_1, and the "forecast" interval is short; while for nonautonomous systems exogenous variables may simple dominate the internal dynamic. Under such circumstances the dynamical model is essentially utilized to perform a time series extrapolation of limited duration, in the fashion of a linear predictor. While this would clearly avoid the problems alluded to in Example 3, it is simultaneously a tacit denial of the mechanism represented by the model structure. This will either discredit claims for the interpretative value of the model as a homomorphism for the modeled system structure or (in the nonautonomous case) force the admission that the major behavioral determinants are factors external to the model.

Conclusions

Some of the implications of this discovery for socioeconomic modeling are 1) the dynamic behavior of such multicomponent systems is not constrained in any significant manner by *a priori* structural requirements (i.e., the form (1) and listed stipulations) and 2) largely subjective decisions made during model formulation (e.g., with respect to the number of interacting components) can have a profound influence on model behavior. Clearly, any decision on component number will only approximate reality and model parameter estimates (obtained by regression analysis of observed time series) will therefore be in error due both to observer statistics and model-induced bias. From Smale's result it is also apparent that 1) plausible arguments can be found to justify models which exhibit *any* behavior and 2) the ability of such a model to simulate any number of conditions provides no guarantee of its accuracy under other conditions (even those which are closely related.) These problems are not unique to the form (1) chosen for illustrative purposes, although the analysis is made particularly simple in this case by exploiting the degeneracy of Example 1. While it is true that alternative model structures and/or more restrictive *a priori* assumptions (e.g., on the M_i) may alleviate their early onset (i.e., at $n=5$), the problems are common to multicomponent nonlinear dynamical systems and are exacerbated under circumstances in which only aggregate observational measures of complicated subcomponent internal dynamics are utilized. In certain respects these facts are consistent with the intuitive view that societal systems are so complicated as to, at least in principle, be capable of any imaginable dynamics. While this may appeal to social philosophers, it does not offer much hope for successful long-term socioeconomic prediction. On the positive side, by demonstrating the essential futility of such efforts may be possible to understand more clearly how they ca be of value in shaping our future.

The legitimate role of formal socioeconometric mode lies not in attempts at accurate long-range forecasting b rather in the heuristic process of discovery and appreci tion of alternative courses, the general fashion in whi they might be negotiated, and how they might be altered l departures from assumed norms. Unfortunately, the i creasing commercialization of computer models ca seriously undermine such efforts. Modelers who pretend offer prediction services without full disclosure of pr prietary computer codes, detailed documentation, ar validation benchmarks stifle the debate essential to the fu therance of these goals.

These matters might be of only academic interest if were not for the fact that such models are increasing utilized in the long-range planning of large-scale publ works. Electric power generation and distribution system water and sanitation projects, transportation and cor munication systems are among numerous examples of tl increasingly large and complex quasi-public faciliti which require long lead times for their planning and co struction. To meet these needs it is entirely natural th corporate planners, public utility boards, and governme agencies would attempt to employ what they perceive to l the "scientific" and "objective" techniques of mode mathematical/computer modeling and forecastin Regretably, these efforts may be seriously compromised l the problems discussed here. Perhaps more tragic are tl circumstances in which the forecasts become self-fulfillir prophecies. For example, "prediction" of increasing co sumer demand can, quite logically, become the justific tion and stimulus for construction of new public worl and the design of rate structures. Self-generated social ar economic pressures may then serve to perpetuate tl "predicted" trends. Ironically, the extent to which it possible for a society to willfully determine its futu course (as distinct from extrapolation of the recent pas may thus be grossly underestimated, to the ultimate detr ment of its citizens. It is important that complicate models and elaborate computer techniques not serve t disguise as objective, value-free forecasts, predictior which are, in fact, an expression of a social philosophy or set of unarticulated assumptions.

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The Department of Energy has turned to the public for help in identifying all possible sites in the U.S. where radioactive material may have been stored or processed in the early years of the atomic age. DOE has been searching government files for more than five years in an attempt to compile a complete listing of such sites. Because many records were misplaced or destroyed over the years, the Department has asked that any member of the public who knows where such work was once done contact the DOE. The sites would have been used for nuclear work from the 1940s through the 1960s, but might be used for non-nuclear purposes today. Information on sites formerly used for processing uranium and thorium ore should be sent to Dr. William E. Mott, Department of Energy, Mail Station E-201, Washington, D.C. 20545.

From May 1979 Bulletin of Atomic Scientists

TO THE EDITOR

July 24, 1979

RE: *"Old Sol Comes of Age—Nukes Suspect,"* in TECHNOLOGY AND SOCIETY, Vol. 7, No. 25, March 1979.

Hereinafter are my thoughts with respect to your article. It is hoped that you will review these comments thoughtfully and I would appreciate your reaction to them as well as the members of your committee.

I have been a member of IEEE for over thirty years and never have I seen such misinformation in one short article. I have had great respect for IEEE and the things for which it stands. I thought all of its members were thoughtful, well-educated people. This article, if it represents even a few members, is a very disappointing piece of work. I hope that other members of our society will respond to you and point out the gross errors in your thinking.

How can you possibly say that "With every passing day, it is becoming increasingly clear, etc., etc., etc." It is the writer's opinion that in no way can you claim you speak for IEEE or for other thoughtful people.

Politicians garner votes by favoring popular programs whether they will work or not. They refuse to face the hard reality that our energy must come from sources with enough energy to provide sufficient quantities for the agricultural and industrial community, as well as for the comforts of life for the people of this nation. This does not make it right for professionals in the field of energy to close their eyes to reality.

We must deal with economics in *any* selected energy course of action.

There is only one source of energy which must be considered for this country in the quantities required. That source is nuclear. Nuclear energy has been proven to be, and will *further* prove to be, the most economical, safest, nomics there is no question that it will solve balance of payments problems and provide the least expensive source of electricity available to mankind.

A brief analysis of solar energy indicates very little possibility of further progress in technology to provide quantities needed at costs which can be afforded by the people of this country. With respect to safety, it is *unsafe.* A mere statistical projection will show that the many problems with it, besides being uneconomical, center about the fact that it is costly and unsafe.

It is unfortunate that IEEE, through your committee, takes this position—possibly because you know that there may be large grants by the Deparment of Energy for research and development which will accrue to the members of IEEE. This is a disservice to this nation if such is the case.

You mentioned that the increase in oil prices will cause solar energy to become more viable. This is a basic fallacy in economic thinking because solar equipments are manufactured using other forms of energy. As the other forms of energy costs increase so will the cost of solar equipments, whether they be panels or photovoltaic cells.

The electric power industry in this country, with its wisdom and research and development, has provided for the energy needs to create a strong nation through the development of the most economical sources. It is now known that nuclear is *the* most economical and must be developed. The industry, over the years, has gone to highly efficient central station power plants with high voltage transmission lines and a well-developed distribution system. This is a viable concept which will be maintained and has provided electricity to every person in the United States in abundance. Our present generation has grown up with it. We certainly hope that they understand where it comes from, how, and why at such good prices. Much of the economics of these matters was worked out in the 20's and 30's by men of high wisdom with respect to engineering and engineering economics.

The economics of solar energy will provide energy only for the affluent unless there is an infusion of inordinate amounts of taxpayers' funds. If this is done, inflation will result and still only the affluent will have the needed energy. In a sense, if this happens, the energy will come mainly from the taxpayers' hard work converted to tax dollars. A case in point is the new solar water heating system installed on the White House roof. One only has to examine the economic rudiments of this system to realize that without a question, more energy has been invested in a system than can ever be derived from the system. Is this the way to solve energy problems? Just examine the dollar and energy investment versus the dollar and energy derived from the system. This is a typical installation.

It would appear that the error by your committee is mainly one of ignorance rather than contrived. It is unfortunate that you do not have power engineers and power engineering economists on your committee. You would then find a whole different conclusion. Any such large

analysis. This is where the solar concept will not perform.

With respect to conservation, it is the writer's opinion that most Americans have done very well when you consider that the United States still has the greatest ratio of Gross National Product to energy used of any country in the world. The American people are to be highly commended for this wise use of energy. There are the redistributors amongst us who would badger the American people into using considerably less amounts of energy to the point of being a country like Nepal, where the use of energy is low and the Gross National Product is zero, with resulting considerable starvation and lack of comfort. There are several other nations in this same catagory. Remember, we are trying to help them.

It is the writer's opinion that there is little chance that by the year 2000 the use of solar energy will exceed three or four percent of the total amount of energy consumed. In any event, the energy derived from solar will be very uneconomical and beyond the reach of practically all citizens of this nation.

The logic you use in discussing the portions of energy provided by nuclear versus other forms, escapes me entirely. The reason that nuclear is not a greater portion of the energy mix at present is due to so-called "environmentalists," and their pressures on the politicians. These people grossly misunderstand the safety of nuclear energy and the fact that environmentally, there is no better way to derive electricity. Nuclear is still outstanding in this respect. It appears that your writing on this matter has been influenced by events at Three Mile Island, which is unfortunate. This is probably because the press did not give fair or equitable coverage to this event. This can be traced to the self-censorship of the press.

It is the hope of the writer that IEEE will respond en-masse to this dichotomous article with a positive approach to proper and economically sound solutions to our problems. It is the writer's opinion that nuclear will play a leading role, or possibly a starring role in the future.

I look forward to receiving your comments and those of your committee regarding these matters.

Archie D. Fellenzer, Jr., P.E.
Consulting Engineer

EDITOR'S RESPONSE

Mr. Fellenzer incorrectly ascribes the contents of the editorial in question to the "IEEE, through your committee" and is incorrect in his assumption that "you claim to speak for the IEEE." He apparently failed to note the statement carried in each issue that "The views and statements published in TECHNOLOGY and SOCIETY are those of the respective authors and not necessarily those of IEEE, its Board of Directors, the Technical Activities Board, or CSIT..."

He also incorrectly ascribes to the author of the editorial the notion that "the increase in oil prices will cause solar energy to become more viable." The editorial was clearly referring to a report of the Federal Government's Sola Energy Policy Committee, made up of representative from 30 federal agencies, where the conclusion wa advanced.

Mr. Fellenzer appears to hold his opinions as articles o faith, not susceptible to factual and reasoned arguments Nevertheless, it may be useful to point out another of th factual errors.

Mr. Fellenzer makes a claim for the superiority of th U.S. over any other country in the ratio of GNP to energ used. Although the significance of this ratio to whateve point he is trying to make is difficult to understand, th claim is factually false. Using 1972 figures, per capita GNI in the U.S. was $5800 and per capita energy use was 8 Kcalories, the highest in the world. But the ratio of thes two is 71.4. Of the 20 most industrially developed nation of the world this is the lowest—not the highest—except fo Canada; it is about equal to the figure for Kuwait! Th figures for a few other countries are given in the tabl below. There is no reason to believe that the relativ figures have changed much since 1972; if anything, th position of the U.S. has deteriorated since a number o countries (e.g. West Germany) have been catching up t the U.S. in GNP without a more proportionate increase i energy use.

	Per capita GNP 1972 $	Per capita energy use	Ratio
Switzerland	5900	26	227
New Zealand	3500	20	175
Austria	4200	25	168
Norway	4800	32	150
France	4200	30	140
Japan	3200	23	138
West Germany	4800	38	126
Sweden	5400	44	123
United States	5800	81	71

Mr. Fellenzer makes a number of *ad hominem* attack on the Editor and members of "your committee," wit charges of "ignorance" and "clos[ing] their eyes t reality." Such attacks usually result from the paucity o logical and factually-based arguments and should not b dignified by a response. (See the editorial in this issue for broader commentary on some of the issues regardin nuclear and alternative sources of energy.)

Dear Norman Balabanian:

Thank you for the excellent isue of *Technology and Society,* of which you are the editor. My faith in my profession has been revived.

Your editorial, "Old Sol Comes of Age—Nukes Suspect," brings out the facts and will start, I hope, the procession to solar energy among the various engineering societies. This must come to pass.

In my opinion, nuclear technology will inevitably lead to state control of society and to a rigidly planned economy. In addition, it is a challenge to the intelligence of man and to the continued existence of humanity.

I became an engineer because as a youngster I always felt that of all professions, engineering was the noblest, for through the engineering specialties we could help the human race. However, as the years went by, I discovered that economic expediency usually took precedence over the public health, safety and welfare. As an example, the mighty Mississippi is used as a sewer by upstream industry and nuclear facilities, even though downstreamers must try to clean and use its water for drinking and other purposes. For instance, how in hell can radioactive tritium be removed from the water? I often wonder if engineers understand that disrupting the rhythm of the earth will interfere with the song of the Universe.

Keep up the good work.

Sincerely,
Steve J. Gadler

To the Editor:

I agree with nearly everything in Frank Turner's article "Modern Science and Technology," in *T & S, 7* (25), 11-14.

My question is: How many of us are there? If there are enough, why do we sit idly by in a world gone mad?

R.A. McConnell
Biological Sciences Dept.
University of Pittsburgh

To the Editor:

I would like to express to you my congratulations for your extraordinary publication; it is an important source of information to me.

Actually I am working as a Maintenance Engineer in the National Telecommunications Enterprise and as a teacher at one Local University. For this reason, I would appreciate very much if you could send your publication regularly to me.

Luis Alberto Perez Perez
Bogota, Columbia

Concerned Scientists

Clearly, the TMI accident was quite serious, much more so than some nuclear apologists would now have us believe. On the basis of what is known about the first hours of the accident, it is possible to come to some rather devastating conclusions about the quality of nuclear reactor safety:

1. TMI-2 came perilously close to a meltdown—Had the reactor been in operation at full power for a year rather than several months—it was brought on-line on December 30, 1978—a massive core meltdown would have occurred during the early hours of the accident. It was only because the inventory of hot fission products was not very great that the core did not heat up much more rapidly. Even so, as many as 50% of the fuel rods in the core may have suffered some damage.

2. The emergency systems were unable to deal with the accident—The successful operation of the emergency core cooling systems depends upon having a Loss-of-Coolant Accident. In the absence of such an accident, and given the situation which developed at TMI, there was no way to bring the low pressure cooling systems, which can rapidly bring the core to a cold shutdown, into operation.

3. The plant was saved by non-safety related equipment-The systems actually used to cool the reactor were those very systems assumed to *fail* in the event of a serious accident. Had the main reactor coolant pumps broken down during the course of the accident, for example, all ability to cool the reactor would have been lost.

4. The plant was not designed to handle the series of events which occurred at TMI—As in the past, events unanticipated by reactor designers and safety experts combined to create a dangerous situation. Ultimately, the plant operators were forced to improvise in order to prevent a core meltdown.

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ENERGY FUTURE — Report of the Energy Project at the Harvard Business School

Edited by Robert Stobaugh and Daniel Yergin, with I. C. Bupp, Mel Horwitch, Sergio Koreisha, M. A. Maidique, and Frank Schuller. 353 pp. New York: Random House. $12.95.

Reviewed by David Redfield, RCA Research Center, Princeton.

Given the steady stream of analyses of the "energy crisis" and the debates that they regularly inspire, it is becoming as important to observe who is speaking as what is being said. The present bold volume merits wide attention on both counts. Capping a six-year study of all major aspects of U.S. energy policy, this report gives a comprehensive diagnosis of our energy ills as well as a prescription for treating them over the next twenty years. The authors (a group of seven with varied backgrounds) have the qualifications necessary to tackle as they do the economic, technological, environmental, political, and social complexities which comprise essential threads of this endlessly complicated pattern.

Nevertheless, this book is clearly written for laymen. Its style is simple—almost conversational—and the details of its various calculations and analyses are relegated to the 70 pages of references and notes at the end or to a provocative appendix. The diligent reader will find several valuable nuggets buried among the notes, but the flow of the text is quite direct and the occasionally startling conclusions are clearly stated.

The message of this book can be rather readily summarized if one is content with a bare-bones sketch: Our increasing dependence on imported oil is intolerable for a number of reasons, only some of which are well known. Replacement of imported oil with our four domestic energy sources—oil, natural gas, coal, and nuclear energy—cannot occur on the scale necessary to meet projected growth in energy demand. The U.S. can, however, increase its efficiency in energy utilization by a very large amount without materially reducing its living standards. By thus reducing demand growth and by speeding the application of renewable energy sources (i.e., solar energy), we can develop a "balanced energy system" by the end of this century. Such a system will provide such large benefits to the economy that substantial federal subsidies are justified to induce the growth of this system.

The strengths of this work, however, are in its informative and lucid analyses which form the basis for those far-reaching conclusions. The evolution of each of our four domestic energy sources and the problems it currently faces are authoritatively summarized with occasionally novel perspectives. The chapter on oil, for example, makes a persuasive argument that the total effective cost for further imported oil is at least $35 a barrel "not counting some potentially quite serious social and political costs." The resource limitations on conventional natural gas—treated in the next chapter—lead to considerations of Mexican gas (too limited), liquified natural gas (also imported), synthetic natural gas ("a long-range possibility at best"), and so on.

Coal is viewed with considerable ambivalence, its abundance seemingly offset by serious "systematic, environmental, and sociological problems" that limit the short-term prospects for major increases in its uses. But "...the need for a synthetic fuels capability is more a matter of national security than of comparative fuel economics..." even though the "rush toward synthetic fuels may have been misdirected..." That is, synfuels are still in the research and development stage. Thus "despite its...abundance, coal will not become our major near-term solution to the energy problem."

The title, "Nuclear Stalemate," of Chapter 5 summarizes its theme: Concerns over safety of nuclear power and radioactive waste disposal are leading to delays and changes in new power plants that increase their costs and worsen their economic competitiveness. The cumulative effect of these factors—aggravated recently by the accident at Three Mile Island—have so limited its growth that *nuclear power offers no solution to the problem of America's growing dependence on imported oil for the rest of this century.* (italics in original text)

Specific recommendations are given to increase our four conventional energy sources, but the prescription for treating these problems centers on "Conservation: The Key Energy Source." Although it is the longest chapter in the book and most of its material is not really new, it should be mandatory reading for every concerned individual. What are the realistic prospects for substantial energy savings? Why haven't we practiced conservation more vigorously? What barriers are there to widespread conservation practices? Will the nation's economic health suffer if energy demand is reduced by conservation? What should the federal government do to promote increased efficiency in energy use? All these issues and more are dealt with clearly and convincingly, culminating in two central conclusions: "The United States can use 30 or 40 percent less energy than it does, with virtually no penalty for the way Americans live..." And the prospective benefits justify programs of fiscal incentives up to 40% of capital costs to industry and up to 50% in the residential-commercial sector.

Beyond conservation, new supplies of energy will be needed; the best prospects are renewable energy sources. It is important to recognize that *active and passive solar heating is a here-and-now alternative...* (italics in original) and that "The potential for solar heating is vast..." As for other solar technologies, biomass, small hydroelectric plants, and small wind turbines offer significant near-term benefits; "the logic of photovoltaic conversion is very persuasive;" but "Big Solar" (power tower, solar power satellite, ocean thermal conversion, and large wind machines) is farther away. Even with these reservations, however, "solar could provide between a fifth and a quarter of the nation's energy requirements by the turn of

the century."

This is strong stuff coming as it does from a business-oriented group whose purpose is "...to come to terms with the realities of the energy problem, not with romanticisms, but with pragmatism and reason...." They are acutely aware of the barriers that must be overcome to make this possibility into a reality, however. Considerable space is devoted to institutional problems such as building codes, needed installation and maintenance skills, "sun rights," and the important role of the utilities. The economics, as always, receive detailed attention with emphasis on letting the marketplace do its work. This requires that its present "distortions must be corrected" to strengthen the role of the market. As with conservation, federal incentives are selected as the best means, with "self-extinguishing tax inventives" of various kinds to provide up to 60% of the capital costs!

Returning to the authors' premises and approach, they stress that to achieve their balanced energy program "We favor reliance on the marketplace... Currently the U.S. price structure for energy is heavily distorted...." "...conservation and solar energy should be given a fair chance in the market system..." Also, *financial incentives for conservation and solar have only a nominal impact on the consumer price index compared with the major impact of imported oil.* And, *The tax revenues lost because of the 1973-74 rise in the price of oil would certainly have paid for all the government's share of the conservation and solar energy called for in the balanced program.* (italics in original)

Perhaps then, the most important lesson of this book is that one need not belong to a fringe group to believe that conservation and solar energy are the path, not "...of altruism, but for pressing reasons of self-interest." And for the long term, "It is not unrealistic to envision a Solar America..."

The Poverty of Power, by Barry Commoner. New York: Alfred A. Knopf, 1976, Bantam Book edition, 297 pp., $2.75. *Reviewed by Douglas Tudhope, Ph.D. Candidate in Computer Science at University of Wales, currently at Syracuse University.*

Barry Commoner's book, *The Poverty of Power,* should be of interest to anyone seeking to understand the seemingly abrupt turn of events that led to nationwide gasoline shortages and talk of an energy crisis. Just ten years ago everything seemed fine. Did it suddenly go wrong? Barry Commoner says no, there is a basic fault in our energy system. In this book he examines the causes of the energy crisis and closely related environmental and economic crises that beset us today.

It is a book well worth reading, for he makes a deep analysis seeking the roots of the problem. His main conclusions, although startling, I find completely convincing. In keeping with his scientific approach, he provides an extensive appendix of notes on the sources which lead to his conclusions.

The most original contribution to this area of study is his use of the second law of thermodynamics to examine how efficiently we are using our energy sources today and how it can be used to help examine the energy crisis. The first law of thermodynamics (conversion of energy) helps to measure the gross energy in a system, but the second law (increasing entropy) can be used to measure energy actually available for work. The first law does not differentiate between waste energy, dissipated as low-grade heat, and useful energy. Thus the second law, and not the first, should be used to measure the efficiency of our energy system. Unfortunately, efficiency is usually defined in terms of the first law, giving inflated and unrealistic results.

The second law tells us that we should thermodynamically match energy sources to tasks and not use high-quality energy, produced at high temperatures, for low-temperature tasks. Thus, we should not use power plant electricity for hot water or space heating. A better method for this purpose is to use the waste heat from power stations (cogeneration). Nuclear energy is thermodynamic overkill, considering the extremely high temperatures required in nuclear power plants and the ultimate tasks for which the electricity is used.

Commoner also analyzes agriculture, transportation, and the petrochemical industry. His ideas on agriculture are especially interesting. He writes that farming should be seen as the capture of solar energy. Our present farming methods are disastrous and will exhaust the soil. The deceptive high yields of today are only a result of spending ever-increasing amounts of energy in the form of artificial fertilizers and pesticides. The net income of U.S. agriculture has decreased since 1950 because of the "green revolution." The sane approach would be to return to a form of organic farming that used the sun to provide energy. Similarly, a sane transportation system would be based on the electric train and not the motor car.

What kinds of energy sources does the science of themodynamics suggest? Fossil and nuclear fuels are inefficient, harmful to the environment, and are becoming increasingly expensive, requiring more and more capital investment. They are becoming expensive because they use nonrenewable (disappearing) fuel sources and unnecessarily complex technologies. The rational way to go is to develop solar energy and other alternative sources. Commoner tries to dispell some of the false myths about solar energy. It has been proved to work; it can be used to provide high-quality energy.

It is perhaps ironic that as late as July 1979, President

Carter proposed to spend more than 20 times as much on synthetic fuels from coal and shale as on solar energy. If anything, these figures should be reversed. To produce liquid fuel from coal or shale runs against all principles of thermodynamics. One third of the coal's original energy is used up in running the process. If this fuel is then used to run cars or trucks its second-law efficiency will be less than 10%.

In search of the underlying cause of the problems that beset us, Commoner delves into the realms of economics and politics. He finds that there has been a major shift in production techniques in the last 30 years towards more capital-intensive, high-energy systems. This causes rising unemployment due to automation and rising inflation due to a shortage of capital. Commoner argues that such a system can only stave off collapse by having never ending growth and by producers passing on the "external costs" of pollution, environmental decay, disease, and health care to third persons. But pollution can no longer be tolerated, and the quest for continual growth comes to resemble an older quest for perpetual motion. Some of Commoner's economic conclusions call for more detailed examination, but his general thesis seems sound.

At last we come to the root of the problem. Commoner concludes, in the final chapter, that the reason why we have such an irrational energy/production system is that decisions are made on the basis of short-term profit for the decision-makers and not on the basis of social need. Decisions based on personal profit cannot lead to a rational system. Commoner gives a telling example of how GM displaced the electric trolley public transport system in Los Angeles to make way for its own buses. The smog in Los Angeles today refutes the old adage that what's good for GM is good for the nation. The name of the hidden disease afflicting our society, says Commoner, is capitalism.

Commoner calls for a production system geared to serve social needs, one that judges the value of products by their use. In his view, this must be a form of socialism. A socialist economy, he says, need not be centrally planned and authoritarian. However he does not develop this idea any further, merely suggesting Eurocommunism as a possible example. This is an unsatisfactory conclusion to the book. It will not be convincing to people who have become repelled by capitalism, are seeking a saner, more humane system, but are not ideologically committed to socialism; and it will be easy to dismiss by those ideologically committed to capitalism. If Commoner wanted to deal with this subject at all, he should have provided his vision of the kind of society he wants, what it would look like, and what kinds of technology it would have.

Indeed he could have found a model in the writings of Peter Kropotkin 80 years ago[1]. Kropotkin was also concerned about how to achieve a rational system of production compatible with individual freedom. For him the solution was anarchism, which opposed authoritarian forms of "socialism," and advocated a decentralized society whose resources would be available to everyone. Kropotkin described how such a society might look. The false distinction between producers and consumers, manual and intellectual work, town and country, would disappear, leaving us with a decentralized society of communities, approaching self-sufficiency in food and energy, with agriculture and industry integrated into the community—"factories amidst the fields."

Although society did not follow Kropotkin's vision in the first part of the 20th century, his ideas seem to be taking root today. They can provide Barry Commoner with a way to achieve a rational and humane energy system. Kropotkin shared Commoner's concern for agricultural techniques and detailed how a "bonanza farm" (agribusiness) in Iowa collapsed in 1878, because the soil had become exhausted and the single crop, wheat, fell victim to disease.

Commoner has been criticized for writing a political book disguised as a scientific one and for using scientific concepts such as "work" and "energy" in social settings, where they do not mean the same and are not valid. The second criticism is a misunderstanding of Commoner's argument. He is not saying that social decisions, value judgements, should be treated like physical equations or that the laws of thermodynamics should control all our decisions. He is saying that since energy is a scarce resource at present, social decisions should take this into account. It is important just now to use energy efficiently, although in some cases we may decide to use a less efficient energy source because of some other consideration. As to the first criticism, it can be argued that the false distinction between science and politics is the cause of many of today's problems. To quote Kropotkin:

> In the meantime the great question—"What have we to produce, and how ?" necessarily remained in the backround. Political economy, as it gradually emerges from its semi-scientific stage, tends more and more to become a science devoted to the study of the needs of men and of the means of satisfying them with the least possible waste of energy—that is, a sort of physiology of society. But few economists, as yet, have recognized that this is the proper domain of economics, and have attempted to treat science from this point of view. The main subject of social economy—that is, the economy of energy required for the satisfaction of human needs—is consequently the last subject which one expects to find treated in a concrete form in economical treatises.

[1] Peter Kropotkin, *Fields, Factories and Workshops Tomorrow*. First published in 1899. Harper Torchbooks edition, 1974. Edited and augmented with additional material by Colin Ward.

Pension Reform Bill To Aid Unvested Employees Introduced in Senate

Proposed Federal legislation in the area of pension reform, which culminates several years of intensive legislative effort by IEEE, has been introduced in the Senate by Alan Cranston (D-CA), Senate Majority Whip. The proposed legislation is designed to provide retirement income to individuals in highly mobile professions who may never vest in an employer-sponsored plan.

The bill, known as "The IRA-Employer Plan Coordination Act of 1979" (S. 1428), embodies a Limited Employee Retirement Account (LERA) concept, which was developed jointly by IEEE and Congressman James C. Corman (D-CA), and is a companion bill to H. R. 628.

The Corman-Cranston measure would modify the Internal Revenue code of 1954 to allow a participant in a qualified pension to contribute to an Individual Retirement Account (IRA) up to the annual IRA limit of $1,500 each year until full vesting occurs. At full vesting, the employee could choose the greater amount—the IRA or the employer pension plan.

If the value of the IRA is more than that of the qualified plan, the individual would yield form the IRA an amount equal to the present value of the plan and pay taxes on it at ordinary rates. If the value of the plan exceeds that of the IRA, then the individual would terminate the IRA and pay taxes on the amount yielded at ordinary rates.

The United States Activities Board (USAB) of IEEE has been instrumental in formulating the proposed legislation which, unlike other pension-reform bills, has certain unique features with respect to equitability and revenue loss. The Corman-Cranston measure, for example, allows the full annual IRA contributions (currently, 15% of earnings or $1,500, whichever is less), until full vesting occurs. However, the bill does not allow an individual to become fully vested in a pension program and also continue a full investment in a LERA account. It also requires a recouping of taxes on investments at such time that full vesting occurs, thereby providing significant offset to the initial revenue loss effects.

The special Pension Task Force of USAB, in consultation with the Joint Committee on Taxation and the U.S. Treasury Department, will continue its efforts to secure passage of the bill.

Robert Baum and Albert Flores, Eds., *Ethical Problems in Engineering,* Rensselaer Polytechnic Institute, Troy, NY, 1978, 335 pp. (P) A collection of case studies, codes of ethics and articles, both historical and contemporary, organized into four parts, each with an introduction. Many items are very short, but the introductions summarize and integrate well.

Philip L. Bereano, Ed., *Technolology as a Social and Political Phenomenon,* Wiley, 1976, 544 pp. A good selection of readings organized into seven areas, with an integrating introduction to each area by the editor.

John G. Burke and Marshall Eakin, Eds., *Technology and Change,* Boyd and Fraser, 1979, 500 pp. (P) A reader of 70 brief essays collected in five sections, each with an introduction. It was developed for the program, called Courses by Newspaper. Because of the brevity of the essays, depth is not achieved but a wide range of topics and authors are covered.

Raymond Bowers, Alfred M. Lee, and Cary Hershey, Eds., *Communications for a Mobile Society: An Assessment of New Technology.* An assessment of the economic, legal, and social implications for industry, medical services, public safety, etc., of land mobile communications. Studies are given of the history, technical details, economics and regulation of the technology. Also analyzes current uses of communications systems by individuals, government, and business and commerce and outlines policy issues.

Barry Commoner, *The Politics of Energy,* Alfred A. Knopf, Ed., 1979, 101 pp. (P) An analysis of the Carter administration energy plan and the politics and economics of energy policy. Argues against nuclear power and in support of solar.

R.J. Congdon, Ed., *Introduction to Appropriate Technology: Toward A Simpler Lifestyle,* Rodale Press, 1977, 205 pp. (P) An edited version of a series of lectures at the Technical Universities of Eindhoven and Twente under the auspices of the Netherlands Universities Foundation for International Cooperation. It is a technically detailed introduction to socially appropriate technology for people in the Netherlands.

Richard C. Dorf and Yvonne L. Hunter, Eds., *Appropriate Visions: Technology, the Environment, and the Individual,* Boyd and Fraser, 1978, 351 pp. (P) The record of a series of programs at the University of California, Davis, addressing the problems of a growing technology, the need for energy conservation, and the maintenance of human values. Major contributions from Barry Commoner and E.F. Schumacher.

Edward Galagher, *A Thousand Thoughts on Technology and Human Values,* Lehigh University, Human Perspectives on Technology, 1979. (P) A collection of sayings and quotations to stimulate thought and discussion about issues relating technology and human values.

Bernard Gendron, *Technology and the Human Condition,* St. Martin's Press, 1977, 262 pp. (P) A critical analysis of some representative views of the social role of technology. It inquires into (a) the nature and extent of the impact of technology on social institutions and individual lives; and (b) the degree to which this impact is beneficial or harmful.

Hazel Henderson, *Creating Alternative Futures,* Berkley Publishing, 1978, 403 pp. (P) A collection of imaginative previously published, but recent, essays with dissenting views on economics, technology and democratic participation in its control.

Hayrettin Kardestuncer, Ed., *Social Consequences of Engineering,* Boyd and Fraser, 1979, 290 pp. (P) Intended as a text for nonengineering students, each chapter of the book deals with a representative area of engineering developments: habitat, energy, communications, computers, pollution, transportation, etc. It also presents broader topics such as technology assessment, risk analysis, genetic engineering and science courts.

Larry Laudan, *Progress and its Problems: Toward a Theory of Scientific Growth,* Univ. of California Press, 1977, 257 pp. (P) Criticism of existing philosophies of science and a redefinition of scientific rationality and progress.

Amory B. Lovins and John H. Price, *Non-Nuclear Futures: The Case for an Ethical Energy Strategy,* Ballinger, 1975, 223 pp. (P) Two physicists individually authored the two separate parts of this book. The first part assesses in a semitechnical manner the fundamental issues related to nuclear power: reactor safety, fuel reprocessing, waste management, and policy questions. The second part analyzes the question of net energy available from a rapidly growing nuclear power system—which has been the expectation of nuclear proponents—and the practical problem of eventually slowing the rate of growth.

technologies—nuclear and nonrenewable fossil fuels—and "soft"—renewable—on the basis of real cost, energy quality and end-use efficiency, scale, equity, and values. Concludes strongly in favor of renewable, solar energy and describes transitional systems to go from here to there.

Clare D. McGillam and William P. McLauchlan, *Hermes Bound: The Policy and Technology of Telecommunications,* Purdue University, 1978, 284 pp. (P) A study of the impact of telecommunications on social behavior, business operations and cultural mores; also the reciprocal impact of societal control and policy decisions on the development and application of the technology of telecommunications.

Denis L. Meadows, Ed., *Alternatives to Growth - 1: A Search for Sustainable Futures,* Ballinger, 1977, 401 pp. (P) A collection of essays dealing with the questions of how to organize a modern society to provide a good life for its citizens without requiring ever-increasing population growth, energy/resource use, and physical output; and what are appropriate policies to facilitate the transition from growth to a steady state.

William D. Metz and Allen L. Hammond, *Solar Energy in America,* AAAS, 1978, 239 pp. (P) A rather complete description of solar energy developments in the U.S. through 1977. Includes appendices on the 1979 federal solar budget, solar supply projections, and wind machines and solar collectors commercially available in 1978.

Dorothy Nelkin, *Technological Decisions and Democracy: European Experiments in Public Participation,* Sage Publications, 1977, 110 pp. A monograph discussing the role of affected citizens in the decision-making process in controversial policy areas involving science and technology. Some specific cases from Sweden, Austria and the Netherlands are presented.

E.D. Pytlik, D.P. Lauda, and D.L. Johnson, *Technology, Change and Society,* Davis Publications, 1978, 288 pp. In effect, two separate books: One part a mixture of abstract discussions concerning humanistic criticisms of technology together with concrete illustrations of specific societies at different levels of development; the second part a superficial overview of major areas usually included in such books: population, resources, energy, the environment, medicine, work and technology assessment.

Stanley Joel Reiser, *Medicine and the Reign of Technology,* Cambridge Univ. Press, 1978, 317 pp. Traces the history of medical innovations and techniques (microscope, stethoscope, electrocardiograph and newer devices). Shows how these have influenced medical practice, changing the basis of diagnostic judgements from "subjective" to "objective" evidence.

Sidney Sononblum, *The Energy Connections: Between Energy and the Economy,* Ballinger, 1978, 260 pp. Describes in nontechnical terms the major perspectives on economic growth and the role of energy in that growth. Has an appendix on the sources and derivation of all the data used. Ends by supporting policies that will expand the supply and use of fossil and nuclear fuels.

Ina Speigel-Rosing and Derek de Solla Price, Eds., *Science, Technology and Society: A Cross-Disciplinary Perspective,* Sage Publications, 1977, 607 pp. Rather than being a collection of essays, the 15 chapters of this book were written by authors from five different countries as part of a design, which included exchanging drafts and discussing them in conferences, sponsored by the International Council for Science Policy Studies. The book has an academic social science tone; none of the authors are engineers.

Manfred Stanley, *The Technological Conscience: Survival and Dignity in and Age of Expertise,* Free Press, 1978, 281 pp. Might be incorrectly classed as an "antitechology" book. The author's real concern is that thought has been "technicized," that scientific and technological concepts (like feedback), language, metaphors and assumptions are misused in contemporary social thought and practise.

Albert H. Teich, Ed., *Technology and Man's Future,* 2nd edition, St. Martin's Press, 1977, 375 pp. (P) An improved and expanded version of the first edition. A selection of readings organized into three parts.

Bruce O. Watkins and Roy Meador, *Technology and Human Values: Collision and Solution,* Ann Arbor Science Publishers, 1977, 174 pp. (P) Examines a range of problems confronting humanity and analyzes the prospects of solving them technologically—both what *can* be done and what *can't* be done—while relating such solutions to human values.

Langdon Winner, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought,* MIT Press, 1977, 384 pp. (P) An analysis of the concepts of technological determinism and control over technological artifacts obscure and even determine the wants those artifacts were presumably designed to satisfy.

Alvin A. Weinstein, Aaron D. Twerski, Henry R. Pishler, and William A. Doneher, *Products Liability and the Reasonably Safe Product: A Guide for Management, Design, and Marketing,* Wiley, 1978, 336 pp. Written by two engineers and two attorneys, the book takes the angle that it is cheaper for manufacturers to produce products to meet legal standards of reasonable scarcity. Ethical responsibility of the engineer for safe designs does not seem to be an issue.

John B. Young, Ed., *Privacy: What is it? Who has it? For how long?* Wiley, 1978, 350 pp. A scholarly book by British experts in a dozen fields. Discusses the development of the concept of privacy; differences in protections afforded Britons and Americans; the impact of the computer and electronics instruments of intrusion; and the conflicts of rights when they collide.

Edward E. Zajac, *Fairness or Efficiency: An Introduction to Public Utility Pricing,* Ballinger, 1978, 119 pp. (P) This monograph seeks to illuminate the problem of how best to balance equity and justice, on the one hand, and economic efficiency, on the other hand, when the government intrudes into the market place. It uses public utility pricing as an example and provides a comprehensive discussion for the noneconomist.

BIBLIOGRAPHER WANTED

In this issue there appears a brief annotated bibliography of some recent books dealing with themes of importance to TECHNOLOGY AND SOCIETY readers. We would like this to become a continuing feature of our publication, expanding it to include bibliographies of periodical articles. Urgently needed is an individual who will volunteer to assume this responsibility. It can be an interesting and informative task. Anyone interested please contact the Editor.

BOOK REVIEWERS WANTED

The bibliography of recent books dealing with themes encompassing the interests of TECHNOLOGY AND SOCIETY started in this issue is on way to keep abreast of evolving intellectual thought in these areas. But and annotated bibliography can serve only to alert a reader to the existence of a book and provide a bare skeleton of the contents, if that. Reading the books themselves would be the most satisfying, but the rapidly increasing number available means that all but a few will remain unexamined.

TECHNOLOGY AND SOCIETY would like to expand its book review section in order to provide readers this service. Hence, we are seeking to expand our list of reviewers. Anyone interested in reviewing appropriate books published within the last year or two please contact the Editor, specifying the areas you would be most interested in.

OBJECTIVITY, CREDIBILITY, AND PROFESSIONAL INTEGRITY

A group of IEEE officials were invited to a meeting in May by the chairman of the Energy Committee to respond to a request for input from a Congressional committee. The letter of invitation to the meeting and the statement submitted to Congress that resulted from the meeting are reproduced here.

May 7, 1979

IEEE Officers and Directors
Group and Society Presidents
Members of the Energy Committee

Dear Colleagues,

The IEEE Energy Commitee has been requested by Congressman Mike McCormack, Chairman of the Subcommittee on Energy Research and Production, House Science and Technology Committee, to submit our views on major safety and reliability issues in the operation of nuclear power stations. The Subcommittee will commence hearings on these issues May 22, and if our input is to be of use, it must be in the hands of the Subcommittee Staff by Tuesday, May 15, 1979.

To respond to this request, the Energy Committee will convene a panel of IEEE members on Saturday, May 12, 1979, at Stouffer's Inn, Crystal City, which is located near the Washington National Airport. The panel is charged with developing a list of Electrical Engineering concerns and issues related to the safe and reliable operation of nuclear power reactors. Our intent is to provide help in identifying the critical issues, not to recommend solutions.

You are invited to attend this meeting. While the Energy Committee will reimburse panel members for their expenses in participating, we will not be able to cover any part of the expenses of others who may attend. If you are not able to attend in person, I suggest that you charge your organization's delegate to the Energy Committee with representing your views and interests. If you wish to attend, contact Bill Herrold (202-785-0017) of the IEEE Washington Staff for reservations and details.

Representative of the issues which will likely be developed are the following:

- system interactions
- common cause failure
- operator training
- accident monitoring
- incident management
- failure and reliability of components

This brief list is only intended to provide understanding of the nature of the panel's work, and is clearly not complete.

I believe this is an opportunity for the IEEE to provide a useful professional service to the Congress. Your continuing support of the IEEE Energy Committee in our work is appreciated.

Sincerely,
Hilton U. Brown, III
Chairman
IEEE Energy Committee

NUCLEAR POWER PLANT SAFETY AND RELIABILITY

to the
Subcommittee on Energy Research and Production
Committee on Science and Technology
United States House of Representatives

Submitted on June 11, 1979

By HILTON U. BROWN, III, Chairman, Energy Committee
Institute of Electrical and Electronics Engineers

The Energy Committee of the Institute of Electrical and Electronics Engineers (IEEE) appreciates this opportunity to submit its views to the House Science and Technology Committee Subcommittee on Energy Research and Production on the issue of the safety and reliability of nuclear power plants. As you know, the IEEE has long been on record in support of nuclear power. At the present time about 30% of our nation's fuel consumption is for the purpose of producing electrical energy. By 1990 this proportion is expected to be 37% and to increase to 50% by the year 2000. If the electrical energy produced by nuclear power plants in 1978 had been supplied by oil-fired stations, an additional 470 million barrels of oil would have been required, increasing our 1978 oil imports by about 12%. This would have increased our imbalance in foreign trade by over $5 billion. By 1985 the additional imports, which would be needed to replace nuclear power, are expected to triple. The economic penalty without nuclear power is a vital concern to our nation and must be evaluated along with the risks.

On May 12, 1979, the IEEE Energy Committee convened a meeting of members with professional backgrounds in the design, manufacture, construction, and operation of nuclear facilities. The purpose of this group was to identify safety and reliability issues which should be addressed. The issues identified and developed do not constitute a comprehensive view of the safety and reliability aspects of nuclear power, but they do summarize the views within their area of competence of a group of professional persons deeply involved in continuing the safe and reliable development of nuclear power.

Institutional Problems

The regulatory environment in which the United States nuclear power industry operates generates an adversary relationship between the regulated and the various regulatory agencies. These adversary relationships have occasionally inhibited the incorporation of safety designs recognized as having potential for improving public protection. Safety issues might be better served by a less adversarial role, possibly patterned after NASA. It does not automatically follow that technical cooperation to improve design compromises the integrity of the regulatory agency. The relationship between the regulatory bodies and the various components of the nuclear power industry is an economic, health, safety and reliabiltiy issue which should be addressed. We strongly recommend the identification of an office within the Nuclear Regulatory Commission, in which issues concerning the safe and reliable operation of Nuclear Power plants can be addressed in an atmosphere of cooperation between the government and industry, rather than under the adversarial relationship which currently exists.

The Regulator's Role in Operational Management

The relationship between the owner/operator of a nuclear power plant and the regulatory agencies is an issue which needs clarification. The owner/operator's responsibility for, and authority to carry out, the normal operations, maintenance, testing, staffing, training, and operational planning should not be abridged. The responsibility of the regulatory agencies in overseeing the operation and insuring compliance with the appropriate safety standards must be more clearly defined. Overlapping and conflicting regulatory review should be eliminated, as it leads to confused responsibility and inefficient operation, as well as unnecessarily diverting resources away from the most effective application of the "defense in depth" philosophy on which nuclear power plant safety is based. We urge that the current regulatory structure be reviewed in a effort to tailor its requirements to the most cost effective fulfillment of our nuclear safety needs.

The Regulator's Role in Incident Management

For this purpose, an incident is defined as a situation in which plant safety limits have been exceeded, or where the plant operator judges that the limits are likely to be exceeded, or where the maximum permissible release of radioactivity has been exceeded. Incident management must address four interrelated requirements: (1) data gathering, (2) decision making, (3) information dissemination, (4) assuring implementation of decision.

Data gathering requires that proper instrumentation ex-

actions required to assure adequate data gathering include indentification of the necessary data, procuring or developing the equipment required to collect this data, and qualifying such equipment for accident environments and post-incident conditions. We strongly urge increased R&D funding by both government and the private sector toward developing more reliable instrumentation to assure the proper evaluation of necessary data during the earliest stages of an incident.

Decision making under emergency conditions requires that proper responsibility and authority for decisions be clearly recognized. This in turn requires that affected bodies (utility, NRC, public, etc.) are coordinated through good planning prior to the incident.

Each of the involved bodies (utilities, NRC, state and local officials, public information officers, etc.) must understand the decision areas for which they are responsible, and the manner in which they are to coordinate their action with the other involved bodies. We strongly recommend appropriate planning with the full participation of each of the responsible groups, with responsibility for determining the adequacy of this planning fully defined.

Information dissemination requires that a central and adequate spokesman be utilized. The public as well as personnel involved in the incident must be kept informed. Different levels of information are required for different users, however, all information released must be as accurate and consistent as possible.

In incident situations the role of the NRC as direct technical advisor to state officials should be clarified. An approved emergency plan should serve as the basis for action by state and local officials. The NRC should advise in the continuation or modification of the plan.

The authority and responsibility of the NRC in the review and approval of strategy proposed by plant management during the course of the incident and until the plant is restored to normal operation or is in a cold shutdown condition is a major issue.

Assuring implementation of decisions is vital to incident management. Those groups or individuals making decisions must have the authority to assure that they are implemented. Since civil authorities have the power to implement evacuation, for instance, they must be included in the planned decision making process.

Human Factors

The human is the vital link in the design, maintenance, and safe operation of a nuclear plant. To reduce the potential for incidents caused or worsened by human factors, the adequacy of information systems available to the operator, together with the adequacy of operational procedures should be the subject of continuous review. The degree of plant automation needs to be reviewed to determine the best balance between automatic control and human decision-making. Attention should be focused on the adequacy of initial operator training and certification. Equipment in a power plant is continually modified, and operational procedures are continuously updated, and there is

Design Criteria and Design Basis for Safety Systems

The major components of nuclear plants are, themselves, complex systems. The interactions between these components is a factor in the performance of safety systems. The adequacy and appropriateness of the design criteria and design basis for nuclear power plant safety systems, taking account of these interactions, is an issue which should be reexamined.

Many of the safety features of a nuclear power plant are designed to deal with the maximum credible accident. Accidents of much greater probability, but with a much lower potential for endangering the public, are not adequately dealt with and could result in releases of radioactivity. We recommend Systems Engineering studies to identify scenarios which might present a hazard to the public, including the combined effects of operator error and mechanical failure, which may be a better criteria and basis for safety design. The scenarios developed should identify the need for additional accurate, unambiguous, and reliable instrumentation. They may also identify requirements for the more automatic processing and presentation of timely information, to guide operator action. A part of the issue of the design basis and criteria for safety systems is also the qualification of safety related equipment.

Public Information

Misinformation or the lack of adequate information on the part of the public can lead to actions on the part of the regulatory agencies which may be counterproductive in terms of nuclear plant reliability and safety. The public needs help in understanding that all activity involves risks, and that the relative risks associated with nuclear power are acceptably low. The risks associated with restricted future energy supplies need to be made more clear. The facts associated with nuclear power need to be pointed out so as to put nuclear power radiation effects in the proper perspective.

The matter of public education is a nuclear power safety issue, because a poorly informed public may force energy policy decisions which will be very detrimental to the environment, and to our way of life.

Two major points emerged from the panel's deliberations. Unambiguous authority and responsibility are primary considerations in the safe development and operation of nuclear power, and more expeditious ways of addressing safety issues than the present adversarial approach might result in still safer systems at lower cost, in both time and money.

The members of the panel have considerable depth in the areas which are discussed above, and we would be pleased with an opportunity to expand upon any of these issues if that should prove useful to you. I hope this material will prove useful in the Subcommittee's work.

This is a remarkable document which raises a number of disturbing implications about the credibility of IEEE public pronoucements.

1. Haste of Response

Invitations were mailed on a Monday to a meeting to be held five (5) days later. Clearly, this timing did not permit the invitees the leisure of reflecting on the issues. Only those with preformed opinions, and those with a direct interest in nuclear power, would be likely to show up. In fact, paragraph 2 of the Statement identifies the attendees as "persons deeply involved in *continuing* (my emphasis) the safe and reliable development of nuclear power." The result delivered to Rep. Mike McCormack, a staunch proponent of nuclear power, is clearly not a dispassionate, objective analysis of the issues from disinterested professionals, but reflects just what the Congressman wanted to hear from like-minded individuals.

2. The Sponsorship of the Statement

The introductory sentence of the Statement clearly states that the IEEE Energy Committee is submitting "its views." Congress is given to understand that what is being presented is the considered position of the IEEE Energy Committee. This understanding is reinforced by the first sentence of the second paragraph, which says that "the IEEE Energy Committee convened a meeting of members." Yet, we know from the invitation letter that far more than Energy Committee members were invited; so exactly what is the sponsorship of the Statement?

In order to clarify this point, I communicated with Hilton Brown. When he returned my calls, he acknowledged that the Statement of June 11 was his own distillation of the deliberations of the [*ad hoc*] group assembled on May 12, and not an official position of the *Energy Committee.*

3. Responsiveness of the Statement to the Panel's Charge

The nature of the issues and concerns which the panel was charged with developing were described in the May 12 letter as being "Electrical Engineering...related to the safe and reliable operation of nuclear power reactors." Yet the Statement ranges far afield. The first paragraph attempts to make a case in support of nuclear power, *regardless of the safety and reliablity*—a matter clearly outside the specified charge. (The way the Statement puts it is that other things besides safety and reliability—like economics and balance of payments—are vital, and so they too "must be evaluated along with the risks.") Most of the other issues treated under various subheadings have no bearing on "Electrical Engineering concerns and issues." Under INSTITUTIONAL PROBLEMS, for example, unhappy that the NRC sometimes does not behave like a subservient part of the nuclear power industry, the Statement's authors would like the NRC to operate more as an arm of that industry. Under the PUBLIC INFORMATION heading, the statement, in effect, recommends a propaganda campaign to convince the public of a specific line: namely, "the relative risks associated with nuclear power are acceptably low!" I would have imagined that this is a matter for debate; that professionals as well qualified as I conjecture the Statement's generators to be, can and do easily challenge that contention. Exactly to whom is the risk alleged to be "acceptable?" When appropriately interpreted, the second paragraph under this heading (consisting of a single sentence) completely exposes the concerns of the Statement's generators. "Poorly informed" should be read to mean "disagreeing with the nuclear industry." The proper interpretation of this paragraph is as follows: *The matter of selling our line is important for the safe continuation of nuclear power because, if the public disagrees with us, they may force energy policy decisions which will be very detrimental to the environment of nuclear power, and to the nuclear industry way of life.*

4. Subsidy to the Nuclear Power Industry

In one of the few items showing adherence to the panel's charge of sticking to Electrical Engineering concerns, under *Data Gathering,* there is a strong call for increased R&D funding to develop more reliable instrumentation—funding not just by the private nuclear industry, *but by the government.* The reasoning as to why there should be government subsidy to a private industry is not spelled out. It is one of the increasingly evident paradoxes (see the Chrysler situation) that those who most vigorously denounce government regulatory interventions in private industry most assiduously seek the same government's largesse.

Neither the technical and professional integrity nor the credibility of IEEE were well-served by the June 11 Statement presented to Congress and the context in which it was prepared. It is evident that the proponents of nuclear power were in a panic over the TMI accident and they sought any possible means for seemingly technically objective groups to go public with reassurances. While it might be considered acceptable by some for a congressman to use the mechanisms of Congress to further his political goals, it is surely not acceptable for a technical/professional society to release a political statement camouflaged as objective, technical judgment. It would seem to me that, at the very least, the Energy Committee would want to clarify the record for Congress and for the members of IEEE.

NORMAN BALABANIAN
6 September 1979

News, Notes, and Comments

Denis Hayes Appointed Director of SERI

The Solar Energy Research Institute is a national laboratory funded by the Department of Energy (DoE) but managed by the Midwest Research Institute. Created by Congress in 1974 (three years before the creation of DoE), but not funded until 1977, SERI started out by taking a conservative view of solar potential. It has been plagued by a confusion of authority with DoE. SERI managers and investigators have attempted to maintain independence from DoE. But the expectation at DoE has been that SERI fulfills the role of a contractor carrying out whatever services DoE requires. Since DoE under Secretary Schlesinger could not be described as a solar booster, it is not altogether surprising that SERI has not been playing a more important role in solar research and development.

That may be changing. SERI's budget for next year has been boosted to the neighborhood of $110 million. And, effective July 26, Denis Hayes, an environmental supporter and solar energy activist, was appointed Director of SERI to replace Paul Rappaport, who had been director since the inception of SERI. The appointment of aggressive and activist leadership is viewed by some as a natural reflection of the adoption by President Carter of the goal of meeting 20 percent of the nation's energy needs by the year 2000 with solar energy. But others suspect that the hiring of Hayes is one way of silencing or neutralizing an effective critic of the Administration's energy policy. Given his entire previous life, it is unlikely that Denis Hayes can be silenced.

Costs of Restarting TMI

General Public Utilities Corporation (GPU), the parent of Metropolitan Edison, has obtained estimates for repairing the damaged nuclear reactor (unit 2) at Three Mile Island and replacing the reactor core. The total is in the neighborhood of $400 million. Furthermore, the NRC will not permit the undamaged TMI unit 1 to restart until at least January 1981. If TMI-1 does not start up until early 1981, the additional losses to GPU will be about $300 million.

(Continued from page 2)

Nuclear Power and Some Lessons . . . .

the accident, TMI-2 was out of control; Metropolitan Edison engineers were uncertain as to what was going on inside the reactor and so the measures they were proposing and carrying out were shots in the dark. "Good luck had as much to do with averting a catastrophe as good engineering," said the April 20 issue of *Science*.

(3) If we did not already know it, we learned about the NRC that:

a. The NRC's first and major concern was to protect the nuclear industry. Far from being an independent agency concerned with the health and safety of the public, the NRC was continuously in contact with the public relations apparatus of the White House and worked hard to make sure only "reassuring" information would reach the public. The single item to which the NRC devoted the most sustained attention during the first few days after the accident was the wording of press releases designed to reassure the public; the Commissioners debated the exact wording for hours! They did this even though they were uncertain as to what was going on, as to the extent of the risk to the local population, or as to what to do. "We are operating almost completely in the blind," said NRC Chairman Hendrie in a meeting; he also told Pennsylvania Governor Thornburgh that the health consequences of the release of radioactive gas have not "been studied or understood in a real way."

b. The NRC had very little confidence in the technical capability of Metropolitan Edison. Said Hendrie, "Met Ed is not all that strong technically." It would be important to learn what opinion the NRC has of the technical competence of other nuclear utilities, and why they issue licenses to companies they consider "not all that strong technically."

c. The NRC would rather that the public be uninformed about the strengths and weaknesses of nuclear plant safety systems. "What's that [constitutional] amendment about freedom of the press?" asked Hendrie, "I'm against it." And now the NRC wants the secrecy provisions of the Atomic Energy Act extended to cover the design and specifications of the nuclear power industry's security systems. (A bill is pending in Congress.) Even though much of what has been learned about the lax standards of security and lost nuclear material has come from requests under the Freedom of Information Act (FOIA), the NRC wants the FOIA to be inoperative. Neither the NRC nor the nuclear industry would any longer have to disclose to the public the information needed for citizens to judge the adequacy of protective systems and thus exercise their democratic rights on the issue of nuclear power. Anyone "blowing the whistle" on industry shortcomings in this area by disclosing "sensitive " information would be subject to criminal penalties.

The invitation extended in the March 1979 issue remains open for someone to present the case for nuclear power in the pages of TECHNOLOGY and SOCIETY. Factually-based rebuttals of any and all issues treated here would be especially welcome. NORMAN BALABANIAN

COMMITTEE ON

SOCIAL IMPLICATIONS OF TECHNOLOGY