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COMMITTEE on SOCIAL IMPLICATIONS of TECHNOLOGY

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EDITORIAL: NUCLEAR POWER AND THE IEEE

The focus of this issue of the Newsletter is energy, a subject which has the most profound implications for organized society and for the nature of the lives we will lead in the decades ahead. It is, therefore, among the issues of greatest concern for CSIT. The specific case of nuclear energy is particularly significant.

Within the last several months, the Executive Committee and the Board of Directors have twice issued statements giving strong support to the rapid development of nuclear electric power. The Executive Committee's statement opposing the California Nuclear Initiative appeared on page 26 of the June 1975 issue of SPECTRUM, although the text of the Initiative itself was not provided. (See pages 10-12 in this issue for both texts.)

The Board of Directors has been under considerable pressure from the proponents of nuclear energy to issue a more general statement strongly endorsing rapid nuclear development. An early draft considered by the Board so totally ignored the wide diversity of views and the polarization within the IEEE community that it sounded like a self-serving publicity release of the nuclear industry rather than an objectively balanced, considered professional judgement. This draft prompted the CSIT to express its deep concern to the IEEE Board. (See text of letter from CSIT Vice Chairman Malvern Benjamin to Executive Vice President Robert F. Cotellessa following this editorial.)

Nevertheless, on January 29 the IEEE Board of Directors issued its statement on "The Need for Nuclear Power" (See text following this editorial). In view of the fact that a number of major studies of a whole range of issues surrounding nuclear energy have recently been commissioned by the National Academy of Science and the Ford Foundation (See News, Notes and Comment), the technical/professional urgency for the Board to issue a statement at this time is not evident. But in view of the California Initiative and other manifestations of opposition to nuclear power, the nature of the urgency was clearly political/ideological.

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In This Issue

With this issue the editorship of the CSIT Newsletter changes hands. As new editor, I shall attempt to maintain the high quality which the Newsletter achieved under Victor Klig. Readers are urged to comment freely, for publication, about any and all features of the Newsletter. Norman Balabanian

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The editorial staff invites letters and articles from readers. We are interested in publicizing news of all upcoming meetings, study groups, discussions, lectures, or workshops that in any way relate to the interaction between technology and society. Correspondence may be sent to any of the above editors. "The views expressed in this Newsletter are those of the respective authors and not those of IEEE."

Less than a year and a half ago, Philip Handler, president of the National Academy of Sciences expressed deep concern over a world energy system based on the nuclear breeder reactor. Looking ahead a century and contemplating the number of reactors this would entail, Handler said:

"...That would mean putting four reactors on line each week for the next century and also replacing those that wear out, an absolutely staggering task. When one adds the nightmare of the existence of the 15,000 tons of plutonium required for that many breeder reactors, the health hazards in handling plutonium, the police effort required so that no plutonium is removed for the construction of illicit nuclear weapons, and the task of waste disposal, one need not invoke the possibility of a catastrophic accident to consider that this is an insupportable scenario. Somehow, the world must skip the breeder reactor and go from petroleum and coal -- solid, liquid and gasified -- to fusion and/or solar energy or it is inconceivable that the human race will avoid a worldwide calamity on so large a scale as to jeopardize the continuing future of our species."

Since that time his harsh view has softened somewhat with the concession that development of the breeder reactor may be necessary to "buy time" until solar and fusion energy are developed. (See Science 190, 5 December 1975). But his earlier observations remain valid.

The beginning point for all proponents of nuclear power is the presumed need for energy. The Board's statement refers to meeting "worldwide needs". Behind this presumption of need is a view of a type of society -- a society which will remain energy intensive; a society which will produce all the types of goods now produced in the most industrially advanced society (The world spent $350 billion on armaments in 1974, is the energy required for this purpose part of "the need"?); a society of continuing "exploitation" of nature and wasteful consumption.

But there can be visualized a different society, with a standard of life superior to that of the U.S. currently, in which people and nature live in harmony. The energy requirement for such a society can be much smaller and perhaps totally obviate the need for nuclear power. At its base, then, the controversy over nuclear power is really over the nature of the society which individuals perceive as providing an appropriate life. But nuclear power proponents unquestioningly and without discussion assume that the historical trend in energy usage in the most energy-wasteful society will continue into the future, throughout the world, so for them "the need" is a given. But in the future, all bets are off; nothing can be taken as given and all hidden assumptions must be brought to light and reexamined.

Norman Balabanian

Text of letter dated January 21, 1976, from J. Malvern Benjamin to Robert F. Cotellessa

Energy stands among the foremost issues at the interface of technology and society, and has therefore been a major concern of the IEEE Committee on Social Implications of Technology. The particular field of nuclear energy is undoubtedly the most complex of the immediate energy issues that we face; it demands the utmost objective analysis of its technological, environmental, and societal facets. That demand has caused the National Academies of Sciences and Engineering, at governmental request, to initiate a major new study of nuclear energy and the alternatives. In discussing that study, Academy of Sciences president, Philip Handler said, "We are aware of the polarization of attitudes on nuclear energy among the public and in the scientific community as well" (Science, 190, 961, 1975).

It is the conviction of the Committee on Social Implications of Technology that any public statement by the IEEE on this subject must present objective analyses of the various aspects of the issue and must reflect the diversity of views that are held by thoughtful, sincere people throughout our society. The draft statements (including revisions available at our meeting of January 10, 1976) submitted for IEEE endorsements do not meet these criteria; they lack both the documentation and the balance that should characterize any IEEE statement.

The CSIT is gravely concerned that the endorsement of any such inadequate position will discredit the IEEE leadership among the members and discredit the IEEE itself in the eyes of the world. We urge that any public statement on this issue be deferred until the criteria set forth in the preceding paragraph are met. The CSIT has the will and the resources to contribute to that goal. This issue is one that is clearly within our area of competence and concern; we therefore further urge that prior to the issuance of any IEEE position related to energy, CSIT be permitted to review and comment on its contents.

STATEMENT BY THE BOARD OF DIRECTORS OF THE IEEE ON THE NEED FOR NUCLEAR POWER

The Board of Directors of The Institute of Electrical and Electronics Engineers, Inc. hereby goes on record as supporting the rapid and orderly development of nuclear electric power.

The supply of energy to meet worldwide needs can be achieved only by making use to the fullest extent of all of the energy options, including wise conservation.

The limited size of known oil and gas reserves, relative to the world's energy requirements, establishes a pressing need to reduce dependence on these sources for the generation of electric power. While there is vast potential in options such as solar energy and nuclear fusion, an appreciable period of time is needed for their development. Therefore, it is deemed necessary to increase emphasis for the remainder of this century on the use of coal and fissionable fuels to provide the bulk of our energy needs. While some engineering and environmental problems are associated with the use of coal and fissionable fuels, these are receiving active attention and evolutionary refinements continually take place. Experience to date indicates that coal and uranium provide unique and practical alternatives to oil and gas. In accord with the need, expressed above, to develop all energy options, the utilization of fissionable fuels should proceed along with an increased use of coal.

The development of safe, efficient nuclear power plants has progressed rapidly and such facilities are now providing a growing percentage of the world's electric power with an outstanding safety record. This development is proceeding in an orderly, highly-regulated manner to insure that the public safety, the disposal of waste material, and security of fuel are taken into account properly and adequately. Therefore, any energy policy should include the increased use of nuclear energy for electric power generation.

The Board of Directors of the IEEE urges all interested and responsible individuals and organizations to take actions to ensure that, in addition to developing other energy sources, the rapid and orderly development of nuclear electric power be stimulated.

January 29, 1976

THE CALIFORNIA NUCLEAR SAFEGUARDS INITIATIVE AND THE IEEE

Frank Kotasek, Jr., CSIT Working Group on Energy and the Environment.

INTRODUCTION

On June 8, 1976 the citizens of California will vote yes or no on an initiative setting forth the conditions under which nuclear power plants will be permitted to operate in the state. The California Nuclear Safeguards Initiative would require the following: (1) Within one year, the federal limits on liability for damages caused by a nuclear accident must be removed by law or by waiver for accidents in the state of California. (2) Within five years, the state legislature must find, by a two-thirds vote, that the effectiveness of reactor safety systems had been demonstrated by actual tests on "substantially similar physical systems" (presumably, large reactors) and that radioactive wastes can be stored or disposed of with no reasonable chance of eventual escape into the environment. Unless these conditions were met, new construction of nuclear power plants would be prohibited and existing plants would be derated and eventually phased out.

Organizers of the initiative campaign include Californians for Nuclear Safeguards and Project Survival and are supported by the Sierra Club and Friends of the Earth. The purpose of the initiative, they say, is to establish whether or not reactor safety systems will work reliably, to force the development of a safe method of radioactive waste storage or disposal before the waste problem reaches unmanageable proportions, and to force the nuclear power industry to back up its claims of nuclear safety by assuming full financial liability for accidents. They believe that the initiative route is the surest way to achieve democratic control of technology.

Opponents of the initiative include the California Council for Environmental and Economic Balance, Citizens for Jobs and Energy, and PES Volunteers from the IEEE Power Engineering Society. They argue that the conditions of the initiative are virtually impossible to meet, that the legislative procedures specified are vulnerable to delaying tactics by nuclear opponents, and that the federal Atomic Energy Act may preempt state action in this field. They strongly object to the two-thirds requirement, which would make it possible for 14 state senators to kill nuclear power in California.

This article surveys some of the issues raised, directly and indirectly, by the California Initiative. The IEEE position statement on the initiative and the text of the initiative itself appear at the end of the article.

PRICE-ANDERSON ACT

There appears to be a contradiction between the nuclear proponents' claims that nuclear reactors are safe and the refusal of nuclear power plant owners or private insurance companies to assume full financial liability for a nuclear accident. One Atomic Energy Commission study estimates that a 1 GWe (10^9 watts electrical) nuclear power plant accident could cause

27,000 fatalities, 73,000 injuries, and $17 billion (1965 $) in property damage.[1] The 1957 Price-Anderson Act sets a limit of $560 million on liability for damage caused by a nuclear power plant accident. If damage awards exceed that amount, the $560 million is apportioned pro rata among the claimants.

Under this law, the reactor owners take out token liability insurance of $125 million per reactor through private insurance companies. The federal government provides the remaining $435 million of liability coverage at cut rate fees.

The standard homeowner's insurance policy contains a nuclear clause which excludes coverage for damage caused by a nuclear reactor accident.

Congress has considered bills requiring that nuclear power plant owners form a liability pool to assume part of the financial risk of nuclear accidents. To put this proposal in perspective, the 42 GWe of installed nuclear generating capacity represents a capital investment of $25 billion and generates $2.8 billion worth of electricity annually. The Ford Foundation Energy Policy Project [2] and the New York City Environmental Protection Administration [3] have recommended outright removal of the liability limits imposed by the Price-Anderson Act.

LIGHT WATER REACTOR SAFETY

The most serious "credible" reactor accident is the large loss of coolant accident, a double break in one of the large pipes which carry the cooling water to and from the reactor core. The loss of moderator and automatic scramming would instantly shut down the reactor, but the radioactive decay of fission products would continue to generate sufficient heat to melt the core. Therefore, emergency core cooling is provided to prevent a core meltdown in the event of any failure of the primary cooling system. There is considerable doubt as to the effectiveness of this emergency core cooling system (ECCS).

If a large pipe break occurred and the ECCS failed to work, the core would melt within 30 minutes, releasing most of its radioactive contents. The steam and gases generated could produce overpressure or a steam explosion sufficient to breach the containment building and release the radioactive material to the environment. Even if the containment building held, the core might melt through the floor of the containment (the so-called "China syndrome"), contaminating the ground water and releasing some of the volatile fission products to the atmosphere.

One way to evaluate reactor safety systems such as the ECCS is to build a test reactor, deliberately subject it to the various types of accidents, and see how well the safety systems perform under accident conditions. In 1970-71, the AEC "Semiscale Blowdown and Emergency Core Cooling Project" conducted a series of 6 ECCS tests on a 9 x 12 inch mock-up of a pressurized light water reactor. The ECCS failed every test--unexpected steam pressure ejected virtually all the emergency cooling water out of the break without cooling the hot fuel rods. ECCS tests under accident conditions have never been conducted on full sized reactors because of their high cost.

The Nuclear Regulatory Commission* relies on computer calculations to evaluate the safety of commercial reactors before they are licensed. Because the phenomena that occur in the course of a loss of coolant accident are highly complex, the computer models include many approximations which, as noted, above, have not been checked against actual tests on full sized reactors. The acceptance criteria model parameters are prescribed conservatively in order to provide a sufficient safety margin to compensate for the approximations. However, prescribing the individual elements of the model conservatively does not necessarily lead to a conservative assessment of total system performance. Moreover, NRC has not established that all of its evaluation model elements are in fact conservatively prescribed. For example, the rate at which the ECCS would reflood the core with emergency cooling water is believed to be only marginally adequate.[4] For a pressurized LWR, the uncertainty in the safety margin is greater than the safety margin itself! One way to increase the ECCS reflood safety margin is to run the reactor at reduced power. This would reduce both the radioactive decay heat and the stored heat, thereby reducing the ECCS reflood rate required to prevent a meltdown.

The NRC safety research program is trying to resolve the questions which have been raised about reactor safety by developing better computer programs. It will verify these programs by system level experiments on its 55 MWt (megawatt thermal) loss of fluid test (LOFT) reactor facility. A study group appointed by the American Physical Society has completed a thorough year-long study[5] of all aspects of light water reactor safety, including the NRC safety research program. The APS study estimates that the results of this NRC project are 4 to 7 years away [6] at current levels of funding (the reactor safety research budgets for 1975 were $53 million for NRC and $36 million for the Electric Power Research Institute). Furthermore, the APS study group doubts that the NRC program, as presently planned, will be able to resolve conclusively the uncertainty regarding ECCS effectiveness. In particular, it questions the validity of scaling up the experimental results from the 55 MWt LOFT reactor to 3300 MWt commercial reactors.[7] The APS study summarizes its findings with respect to ECCS performance as follows:

> "We have no reason to doubt that the ECCS will function as designed under most circumstances requiring its use. However, no comprehensive, thoroughly quantitative basis now exists for evaluating ECCS performance, because of inadequacies in the present data base and calculational codes. In addition, it is not clear that the present approximate calculations, even though based on generally conservative detailed assumptions, will in all cases yield conservative assessments of ECCS performance.
>
> We have examined the AEC reactor safety research program intended to resolve these uncertainties....We doubt that a complete quantitative evaluation of ECCS effectiveness can be achieved through the present program. We recommend below several possible approaches for improvement.

*In January 1975, the Atomic Energy Commission (AEC) was split into two independent agencies, the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC).

The ECCS safety margin should be quantified, and if necessary, improved through one or more of the following approaches:

*the substitution of more easily analyzable or more effective ECCS concepts;

*a much stronger theoretical and calculational development effort combined with a much improved experimental program, the results of which must be published openly for evaluation by the technical community;

*a series of large-scale experiments along with some standardization of reactors."[8]

The ECCS was not their only area of concern. Other APS study group recommendations include:

* Devote more attention to all possible types of accidents--not just the large loss of coolant accident, or "design basis accident." (The Rasmussen reactor safety study[10] found that meltdown accidents initiated by small pipe-breaks and by transients are far more likely than meltdowns initiated by large pipe-breaks);

* More research into the mechanism of steam explosions following meltdown;

* Develop a system of controlled, filtered venting in case of containment overpressure;

* Study of "core catcher" designs to prevent melt-through;

* Assessment of the benefits vs. costs of alternative siting policies such as remote, underground, and nuclear "park" siting.

* Develop strategies to mitigate the consequences of a radioactive release;

* Improve human engineering of reactor controls;

* Recalculate the Rasmussen reactor safety study consequence estimates, taking into account modifications suggested by the APS study group. (As a result of this recommendation, the accident consequence estimates in the Rasmussen study have been revised upward.)

The APS study group concludes:

"Because of the serious potential consequences of a major release of radioactivity, and in view of existing safety-related technological opportunities, we believe that there should be a continuing major effort to improve light-water reactor safety as well as to understand and mitigate the consequences of possible accidents."[9]

SPENT FUEL REPROCESSING AND WASTE DISPOSAL

Approximately once a year, a portion of the reactor fuel is replaced. The fuel rods are removed from the reactor, stored under water for 4 months to allow the short-lived radioactive isotopes to decay out, and shipped in special casks to the fuel reprocessing plant. (see Spectrum, Sept. 1975, pp 63-64) There the fuel rods are chopped into pieces, their contents dissolved in acid, and the uranium and plutonium extracted.

The residue remaining after reprocessing is a concentrated, corrosive, highly radioactive liquid, which would boil continuously from its radioactive decay heat if it were not stirred or cooled. These high level liquid wastes contain radioactive fission products (strontium-90, cesium-137, etc.) and small amounts of transuranic actinide elements (plutonium-239, americium-243, etc.). Because they are intense alpha emitters, the actinides are especially hazardous. The alpha particles have high kinetic energies (typically 5 Mev) and interact very strongly with matter to produce intense ionization. They can penetrate only about .002 inch into living tissue before giving up all of their kinetic energy. Thus a small quantity of alpha emitter is relatively harmless outside the body but, if inhaled or swallowed, it causes intense localized cell damage and a high risk of cancer. Plutonium tends to spread in extremely fine particles, which readily lodge in the lung, and is therefore regarded as one of the most toxic substances know--no one is quite sure how toxic.

The fact that we are leaving our radioactive garbage as a legacy to future generations raises a serious moral question--the right of one generation of humans to create potentially catastrophic hazards for future generations. Because the actinides have long half-lives (24,000 years for plutonium-239), the high level wastes must be isolated from the environment for at least 250,000 years. None of the disposal techniques proposed can guarantee immunity from natural disturbances or man-caused intrusions over such a time scale.

If the transuranic actinides were removed, the high level wastes would still have to be isolated from the environment for 800 years while the fission products decay. This is a more manageable (but as yet unsolved) problem. Thomas C. Hollocher of the Union of Concerned Scientists recommends improving the chemistry of fuel reprocessing to separate almost totally the long-lived actinides from the fission products. The recovered actinides could then be disposed of through transmutation and fission in nuclear reactors. The extraction of U, Np, and Pu should be 99.95% complete and that of Am and higher actinides should be 99% complete. At present the only actinides recovered are U and Pu, both at the 99.5% level.[11] However, there is some doubt as to the feasibility and effectiveness of improved actinide separation.[12]

The high level liquid wastes are stored in underground steel tanks at the site of the reprocessing plant. After 3 to 5 years, the rate of heat production decreases to the point where the water can be removed and ultimate disposal can be considered. Techniques are being developed to convert the wastes into glassy or ceramic solids which are very insoluble in water. In this way the 6000 gallons of high level liquid wastes produced annually per 1 GWe reactor can be reduced to 60 cu ft. Current regulations require solidification of these wastes within 5 years and shipment of the resulting solids to a federal waste repository within 10 years. Neither the federal repository nor the solidification facilities exist at present.

Various types of permanent disposal sites are under study or have been proposed, including ancient bedded salt deposits, other geologic formations, the Antarctic ice cap, oceanic trenches, and solar orbit (see Spectrum, Sept. 1975, pp 60-63 and reference [13]). Burial in salt deposits appears to be a

promising option, provided the actinides have been removed from the wastes. The AEC studied one such site, the salt beds at Lyons, Kansas, but found that there was a risk of water entering the site as a result of previous salt mining and oil drilling operations. The AEC (ERDA) has decided to postpone its choice of an ultimate disposal option and will build a temporary retrievable surface storage facility where solid wastes will be stored until a long term solution is found. It is also studying a "pilot" storage vault to be excavated in a salt bed 3500 ft beneath the desert in southeastern New Mexico.

There are already 90 million gallons of high level liquid wastes in temporary storage, mostly from the production of plutonium for nuclear weapons. The storage tanks were designed to have a life expectancy of 50 years minimum. As of June 1973, at least 15 of these tanks had developed leaks and 420,000 gallons of radioactive liquid wastes had seeped into the ground.

Large quantities of low level radioactive wastes are also produced by all of this chemical processing and routinely discharged into the environment. Intermediate level solid and liquid wastes, heavily contaminated with plutonium, are merely buried in trenches. As much as 300 kg of plutonium from these wastes may have leached into the ground at the Hanford/Richland site. An AEC report states:

"Due to the quantity of plutonium contained in the soil of [trench] Z-9 it is possible to conceive of conditions which could result in a nuclear chain reaction."[14]

Thomas C. Hollocher gives the following assessment of the nuclear waste management problem:

"In retrospect, it is now clear that mistakes were made early in the technology of storage of high level wastes arising from the weapons program. It is interesting that the mistakes were occasioned, in part at least, by the fact that hasty decisions and shortcuts were forced by what seemed to be the overriding national need for bomb-quality plutonium. It is not necessarily true that all facets of a new technology can be forced into efficient operation at the same rate. The lessons learned as the result of weapons technology should be carefully applied in the nuclear power industry.... Waste storage and disposal represent certainly two of the most crucial problems facing the nuclear power industry. Incorrect decisions in this decade could lead to enormous expenses in the next two decades and possibly even to a crippling of the nuclear power industry."[15]

THE LIQUID METAL FAST BREEDER REACTOR

It is estimated that U.S. uranium reserves are adequate to fuel "only" 600 (1GWe)* light water reactors over their 30-40 year lifetimes.[16] Therefore, "inexhaustible" fission power implies development of the liquid metal fast breeder reactor, which converts the abundant isotope uranium-238 into fissionable plutonium-239. Certain properties of the LMFBR make it inherently more hazardous than the LWR.[17] Two of the three LMFBRs built in the U.S.A. have experienced core meltdowns.

*Total present U.S. electric generating capacity is 450 GWe.

In the Fermi reactor meltdown, the calculated "maximum credible accident"--the melting of a single fuel assembly--was exceeded in the event, when three fuel assemblies melted. The "plutonium economy" created by the LMFBR would make our society vulnerable to plutonium theft by terrorists, criminals, and lunatics. Perhaps the LMFBR issue is epitomized by the question: Does it make sense to convert several hundred tons per year of relatively harmless uranium-238 into highly toxic plutonium-239?

The total cost of developing a commercially useful LMFBR is estimated at over $10 billion. The Ford Foundation Energy Policy Project recommends that "the present open-ended commitment to the LMFBR demonstration project be terminated immediately" and that an independent National Academy of Sciences study precede any further funding of the LMFBR.[18] Thomas Cochran argues that the breeder program is premature and would absorb disproportionate amounts of capital just when non-fission energy alternatives are poised for major breakthroughs.[19] Federal energy R&D funding for 1975 included $475 million for the LMFBR, $50 million for solar energy, and $7 million for wind turbines.

OTHER CRITICISMS OF NUCLEAR POWER

Other potential hazards of nuclear power include spent fuel transportation accidents, reprocessing plant accidents, occupational health hazards at mines and reprocessing plants, nuclear proliferation, and disposal of radioactive uranium mill tailings. To put nuclear hazards in perspective, nuclear proponents point out that society routinely accepts far greater hazards, such as the 50,000 annual deaths from motor vehicle accidents.[20] While such statistics are deplorable, they are not entirely relevant--nuclear power imposes hazards on future generations without their consent.

Theoretical risk calculations such as the Rasmussen reactor safety study notwithstanding, it is not yet clear that the overall risk created by nuclear power will be sufficiently small. Scientists, engineers, nuclear industry personnel, and computer models are far from infallible. In complex technological systems, highly improbable events have a way of happening anyway, as demonstrated by the 1965 Northeast power blackout and the sinking of the "unsinkable" Titanic. Before Browns Ferry, hardly anyone would have guessed that a workman with a candle could start an electrical fire that would knock out two of the nation's largest reactors and narrowly miss causing a disastrous meltdown. Nobel laureate Hans Bethe once testified that a core meltdown accident at the Fermi LMFBR would be "incredible and impossible."[21]

It would seem prudent to resolve the critical problems before, not after, a high level of nuclear generating capacity is installed. In the meantime, we should seriously explore alternative energy options while investment in and dependence on nuclear power is still modest.

THE NEED FOR NUCLEAR POWER

Known world oil reserves are only adequate to last 25 to 50 years at projected rates of consumption. Clearly, we must now begin to reduce our dependence on oil. Proponents of coal and nuclear power claim that none of the other alternatives are likely to contribute significantly to our energy supply in this century.[22] Energy from waves, ocean thermal gradients, and fusion is far off in the future. Solar-thermal-electric and photovoltaic conversion are unlikely to be economically competitive very soon. Energy from tides is negligible. Solar space heating and cooling and improved insulation are most economical when integrated into new construction and will be phased into a slowly changing pool of housing and commercial buildings. Nuclear proponents argue that the apparent attractiveness of unproven technologies results in part from our ignorance of their details--fission power itself was once regarded as a panacea.

On the other hand, residential solar hot water heating and geothermal electric power generation are economically competitive now, and each could supply 3% of our energy needs. Solar agricultural and industrial process heat and conversion of forest, farm, and municipal wastes to fuel are rapidly becoming competitive. Improved efficiency in transportation, which accounts for 27% of our energy budget, could significantly reduce our energy needs.

Proponents of wind power claim that wind turbines could begin supplying a considerable fraction of our electric power needs in the near future--200 GWe by 1990--without straining U.S. industrial capacity. The technical feasibility of wind-electrical conversion is well established, with 80 years of experience, including a 1.25 MWe wind turbine which fed electricity into the Central Vermont power grid in the period 1941 to 1945. They claim that wind-electrical conversion with energy storage is already competitive with nuclear power.[23]

Of course, the costs of "external" disamenities (pollution, long-lived radioactive wastes, etc.) associated with fossil and nuclear power are not included in economic comparisons. Moreover, the nuclear power industry benefits from ongoing public subsidies such as the capital cost of government-built fuel enrichment plants, the limits on nuclear accident liability, and the artificially high price at which uranium recovered from spent fuel is sold back to the government.

Coal fired power plants are estimated to cause 30 to 80 deaths per GWe-year, due mainly to sulfur dioxide and small particle emissions. This figure might be reduced to 3 to 8 deaths per GWe-year by installing scrubbers to remove the SO_2, but would still be an order of magnitude higher than total deaths per GWe-year from nuclear power, even assuming nuclear accidents are as likely as critics claim. Nuclear proponents point out that nuclear technology is still in a learning period and claim that accident risks will be reduced by another order of magnitude by the year 2000.[24]

Coal deaths, too, will be further reduced by such processes as coal gasification, liquefaction, and fluidized bed combustion, which may be commercially available within a decade. However, fossil-fueled power plants will still generate carbon dioxide. The CO_2 level in the atmosphere has increased 10% in the last century and, if recent trends in fossil fuel consumption continue, could rise another 20% by the year 2000.[25] The effects of this CO_2 are impossible to predict, but global climatic changes with a significant adverse impact on world agriculture are quite possible. In addition, roughly one square mile of land has to be strip-mined per GWe-year of electrical energy.

GROWTH

Is the energy crisis a case of inadequate supply or excessive demand? The answer depends largely on one's attitude towards growth.

Some would argue that a steady growth rate (i.e., exponential growth) of energy supplies is needed to prevent economic depression, raise our standard of living, provide jobs, reduce poverty, and avoid social unrest, while at the same time enabling us to control pollution, extract metals from lower grade ores, and synthesize substitutes for depleted resources. If one takes exponential energy growth as a "given", then the energy crisis is basically a technical problem, amenable to technical solutions such as nuclear power.

However, I find the arguments in favor of zero energy growth for the "overdeveloped" nations to be far more persuasive. The energy crisis is only one symptom of a more fundamental problem of world development: the failure of the human race to adapt to its finite physical environment. The root problem is not technical, but political, social, and even psychological. Its solution will require changes in society and its institutions, and in the values, perceptions, and lifestyles of individuals. It involves learning to live in harmony with nature rather than trying to "conquer" nature; seeking to improve our quality of life rather than our gross national product; shifting our concept of the good life away from more and more consumption of goods to a greater appreciation of services, leisure, and pleasurable activities having minimal environmental impact; and developing a technology which treats our planet as a living ecological system--not just a lump of minerals. It involves developing a sense of identification with future generations--a lifestyle designed for permanence and based on equilibrium between humans and their environment. It means becoming aware of the interdependence of all the peoples of the world. Clearly, replacing quantitative growth with qualitative growth does not mean stagnation.[26]

The elimination of unemployment and poverty should be an explicit, highest priority goal of our society, not a hoped-for side effect of mindless exponential growth. If one includes the external costs, the age of abundant, low-cost energy as a panacea for society's problems is over. Even if all of their other environmental problems were somehow solved, fossil and nuclear power would still add heat to the environment. A large increase in global thermal pollution will cause climatic changes and, ultimately, a catastrophic rise in the earth's temperature. To put exponential growth in perspective, total estimated recoverable world coal deposits would last 5000 years at current rates of consumption, but would last only 113 years if consumption increases at the projected rate of 5% per year.

Perhaps a key question is whether rapid growth of coal and/or nuclear power over the next 25 years will exacerbate or mitigate the long term problems of energy pollution and scarcity. On the one hand, growth could generate the extra capital and industrial base needed to develop and deploy solar power conversion systems. On the other, it is doubtful that the economic benefits of coal and nuclear power will be plowed back into energy development unless our society drastically reorders its priorities. It is more likely that coal and nuclear power will

encourage us to continue "business as usual" until the tolerance margins separating us from irreversible ecological disaster are drastically reduced. At the same time, if we continue to ignore external costs, the lower economic cost of coal and nuclear power will discourage the development of solar power, so that our options will be severely limited when the real crisis does come.

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[17] e.g., higher power density, higher operating temperature, smaller cooling channels, smaller Doppler broadening coefficient, reactivity increases if coolant boils or is lost, control more delicate due to fewer delayed neutrons and shorter prompt neutron lifetime, 20% fuel enrichment makes nuclear explosion possible following meltdown, sodium reacts explosively if it comes in contact with water, air, or nuclear fuel, and high plutonium inventory increases potential contamination from an accident. Properties which enhance LMFBR safety are lower pressures in the reactor, greater margin between normal coolant operating temperature and its boiling point, and higher thermal conductivity of coolant.

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TEXT OF CALIFORNIA NUCLEAR SAFEGUARDS INITIATIVE

THE PEOPLE OF THE STATE OF CALIFORNIA DO ENACT AS FOLLOWS:

Sec. 1. Title 7.8 (commencing with Section 67500) is added to the Government Code, to read:

TITLE 7.8. LAND USE, NUCLEAR POWER LIABILITY & SAFEGUARDS ACT

67500. This title shall be known and may be cited as the Nuclear Safeguards Act.

67501. The people and the State of California hereby find and declare that nuclear power plants can have a profound effect on the planning for, and the use of large areas of the State, as do related facilities connected with the manufacture, transportation, and storage of nuclear fuel, and the transportation, reprocessing, storage, and disposal of radioactive materials from nuclear fission power plants.

67502. The people further find and declare that substantial questions have been raised concerning the effect of nuclear fission power plants on land use and land use planning, as well as on public health and safety. Such questions include, but are not limited to:

(a) the reliability of the performance of such plants, with serious economic, security, health, and safety consequences;
(b) the reliability of the emergency safety systems for such plants;
(c) the security of such plants, and of systems of transportation, reprocessing and disposal or storage of wastes from such plants from earthquakes, other acts of God, theft, sabotage, and the like;
(d) the state of knowledge regarding ways to store safely or adequately dispose of the radioactive waste products from nuclear fission power plants and related facilities; and
(e) the creation by one generation of potentially catastrophic hazards for future generations.

67503. A nuclear fission power plant and related facilities may be a permitted land use in the State of California and its waters and considered to be reasonably safe and susceptible to rational land use planning, and may be licensed by state or local agencies, and may be constructed in the State only if all of the following conditions are met:

(a) after one year from the date of the passage of this measure, the liability limits imposed by the federal government have been removed and full compensation assured, either by law or waiver, as determined by a California court of competent jurisdiction and subject to the normal rights of appeal, for the people and businesses of California in the event of personal injury, property damage, or economic losses resulting from escape or diversion of radioactivity or radioactive materials from a nuclear fission power plant, and from escape or diversion of radioactivity or radioactive materials in the preparation, transportation, reprocessing, and storage or disposal of such materials associated with such a plant; and
(b) after five years from the date of the passage of this measure
(1) the effectiveness of all safety systems, including but not limited to the emergency core cooling system, of any nuclear fission power plant operating or to be operated in the State of California is demonstrated, by comprehensively testing in actual operation substantially similar physical systems, to the satisfaction of the Legislature, subject to the procedures specified in Section 67507; and
(2) the radioactive wastes from such a plant can be stored or disposed of, with no reasonable chance, as determined by the Legislature, subject to the procedures specified in Section 67507, of intentional or unintentional escape of such waste or radioactivity into the natural environment which will eventually adversely affect the land or the people of the State of California, whether due to imperfect storage technologies, earthquakes or other acts of God, theft, sabotage, acts of war, governmental or social instabilities, or whatever other sources the Legislature may deem to be reasonably possible.

67504.
(a) If within one year from the date of the passage of this measure the provisions of subsection 67503(a) have not been met, then each existing nuclear fission power plant and such plants under construction failing to meet the conditions specified in subsection 67503(a) shall not be operated at any time at more than sixty percent of the original licensed core power level of such plant.
(b) Beginning five years from the date of the passage of this measure, each existing nuclear.fission power plant and each such plant under construction shall not be operated at any time at more than sixty percent of the licensed core power level of such plant and shall thereafter be derated at at a rate of ten percent per year of the licensed core power level of such plant, and shall not be operated at any time in excess of such reduced core power level, unless all of the conditions enumerated in Section 67503 are met.

67505. The provisions of Section 67503 and 67504 shall not apply to small-scale nuclear fission reactors used exclusively for medical or experimental purposes.

67506. One year from the date of the passage of this measure, the Legislature shall initiate the hearing process specified in Section 67507, and, within three years from the date of the passage of this measure, determine whether it is reasonable to expect that the conditions specified in Section 67503(b) will be met. Unless the Legislature determines that it is reasonable to expect that the conditions of Section 67503(b) will be met, then nuclear fission power plants shall be a permitted land use in California only if such existing plants and such plants under construction are operated at no more than sixty percent of their licensed core power level. Unless the determinations specified in this section are made in the affirmative, then neither the siting nor the construction of nuclear fission power plants or related facilities shall be permitted land use in California.

67507. The determinations of the Legislature made pursuant to subsection 67503(b) and 67506 shall be made only after sufficient findings and only by a two-thirds vote of each house.

(a) To advise it in these determinations, the Legislature shall appoint an advisory group of at least fifteen (15) persons, comprised of distinguished experts in the fields of nuclear engineering, nuclear weaponry, land use planning, cancer research, sabotage techniques, security systems, public health, geology, seismology, energy resources, liability insurance, transportation security, and environmental sciences; as well as concerned citizens. The membership of this advisory group shall represent the full range of opinion on the relevant questions. The group shall solicit opinions and information from responsible interested parties, and hold widely publicized public hearings, after adequate notice, in various parts of the State prior to preparing its final report. At such hearings an opportunity to testify shall be given to all persons and an opportunity to cross-examine witnesses shall be given to all interested parties, within reasonable limits of time. The advisory group shall make public a final report, including minority reports if necessary, containing its findings, conclusions, and recommendations. Such report shall be summarized in plain language and made available to the general public at no more than the cost of reproduction.
(b) To ensure full public participation in the determinations specified in subsection 67503(b) and Section 67506, the Legislature shall also hold open and public hearings, within a reasonable time after the publication of the report specified in subsection (a) of this section, and before making its findings, giving full and adequate notice, and an opportunity to testify to all persons and the right to cross-examine witnesses to all interested parties, within reasonable limits of time.
(c) All documents, records, studies, analyses, testimony, and the like submitted to the Legislature in conjunction with its determinations specified in subsection 67503(b) and Section 67506, or to the advisory group described in subsection (a) of this section, shall be made available to the general public at no more than the cost of reproduction.
(d) No more than one-third of the members of the advisory group specified in this section shall have, during the two years prior to their appointment to the group, received any substantial portion of their income directly or indirectly from any individual, association, corporation, or governmental agency engaged in the research, development, promotion, manufacture, construction, sale, utilization, or regulation of nuclear fission power plants or their components.
(e) The members of the advisory groups shall serve without compensation, but shall be reimbursed for the actual and necessary expenses incurred in the performance of their duties to the extent that reimbursement is not otherwise provided by another public agency. Members who are not employees of other public agencies shall receive fifty dollars ($50) for each full day of attending meetings of the advisory group.
(f) The advisory group may:
(1) Accept grants, contributions, and appropriations;
(2) Create a staff as it deems necessary;
(3) Contract for any professional services if such work or services cannot satisfactorily be performed by its employees;
(4) Be sued and sue to obtain any remedy to restrain violations of this title. Upon request of the advisory group, the State Attorney General shall provide necessary legal representation.
(5) Take any action it deems reasonable and necessary to carry out the provisions of this title.
(g) The advisory group and all members of the advisory group shall comply with the provisions of Sections 87100 through 87312 inclusive, of Title 9 of the California Government Code.
(h) Any person who violates any provision of this section shall be subject to a fine of not more than ten thousand dollars ($10,000), and shall be prohibited from serving on the advisory group.

67508
(a) The Governor shall annually publish, publicize, and release to the news media and to the appropriate officials of affected communities the entire evacuation plans specified in the licensing of each nuclear fission power plant. Copies of such plans shall be made available to the public upon request, at no more than the cost of reproduction.
(b) The Governor shall propose procedures for annual review by state and local officials of established evacuation plans, with regard for, but not limited to such factors as changes in traffic patterns, population densities, and new construction of schools, hospitals, industrial facilities, and the like. Opportunity for full public participation in such reviews shall be provided.

Sec. 2. There is hereby appropriated from the General Fund in the State Treasury to the legislative advisory group created by Section 67507 of the Government Code the sum of eight hundred thousand dollars ($800,000) for the expenditures necessary in carrying out the responsibilities and duties set forth in Section 67507 of the Government Code.

Sec. 3. Amendments to this measure shall be made only by a two-thirds affirmative vote of each house of the Legislature, and may be made only to achieve the objectives of this measure.

Sec. 4. If any provision of this measure or the application thereof to any person or circumstances is held invalid, such invalidity shall not affect other provisions or applications of the measure which can be given effect without the invalid provision or application, and to this end the provisions of this measure are severable.

SUMMARY OF THE CALIFORNIA INITIATIVE (PREPARED BY STATE ATTORNEY GENERAL) Nuclear Power Plants. Initiative Statute. After one year, prohibits nuclear power plant construction and prohibits operation of existing plants at more than 60% of original licensed core power level unless federal liability limits are removed. After five years, requires derating of existing plants 10% annually unless legislature by two-thirds vote, has confirmed effectiveness of safety systems and waste disposal methods. Permits small-scale medical or experimental nuclear reactors. Appropriates $800,000 for expenses of fifteen-person advisory group and for legislative hearings. If the proposed initiative is adopted, undefined additional financing from state sources will be required in the amount of at least $800,000. However, if this initiative should restrict the operation of existing nuclear power plants, and the courts should uphold such action, there is a potential for substantial state damage claims from the owners of the plants.

IEEE POSITION STATEMENT ON THE CALIFORNIA INITIATIVE*

The following IEEE position statement on the "California Nuclear Initiative" (proposed moratorium on nuclear plants) has been approved by the Executive Committee, Region 6 Director Carlton Bayless, and representatives of the Western States Intersociety Legislative Advisory Project.

The Institute of Electrical and Electronics Engineers, Inc., hereby goes on record as opposed to the California Nuclear Initiative.

The pressing need to reduce the dependence on oil and natural gas for the generation of electric power has increased the emphasis on use of coal and uranium fuels. There are some future engineering and environmental developments required, regarding the use of these fuels, but the experience to date indicates that each provides a practical alternative to oil and gas.

The development of safe, efficient nuclear power plants has progressed rapidly and such facilities are now providing a significant percentage of the nation's electric power with an outstanding safety record. This development is progressing in an orderly, highly regulated manner to insure that the security of fuel, the disposal of the waste material, and the public safety are properly taken into account. The ongoing program should provide the increased, safe use of nuclear energy for additional electric power generation urgently needed by the industrialized nations.

The proposed California Nuclear Initiative, if passed, could severely disrupt the orderly development and introduction of nuclear-powered electric power plants in California, and perhaps lead to similar action in other states. This Initiative could in effect become a moratorium on nuclear plant construction in California and phase out existing facilities in that state. It is in light of these concerns that the Institute of Electrical and Electronics Engineers, Inc., expresses this position.

*Spectrum, June 1975, p. 26.

ENVIRONMENTAL EFFECTS OF THERMONUCLEAR FUSION POWER REACTORS

Rowland F. Pocock, CSIT Working Group on Energy and the Environment

In March 1973, with the energy crisis dominating the political scene, the British government agreed to an expansion of the country's thermonuclear fusion research programme. This work, at the Atomic Energy Authority's Culham Laboratories, is a truly international project financed partly from Euratom resources. Similar programmes exist in France and Germany, while laboratories in the U.S.A. and the Soviet Union appear to be devoting even greater effort to the problem of harnessing the hydrogen bomb reaction than do those of Western Europe.

This intensification of the fusion research programme has coincided with renewed public concern for the environment. Several writers, noting that no long-lived solid radioactive wastes are produced by the spent fuels claim that the fusion reactor is the most promising solution to the energy/environment problem. Unfortunately, while these opinions are often expressed in publications intended for wide popular appeal (e.g., (1), (2)), more cautious assessments from scientists and engineers employed in fusion research are confined to specialised journals. The information reaching the general public tends therefore to include a certain implicit bias.

I have no direct professional involvement either in fusion research or in environmental monitoring; my sources of information on these subjects are therefore only those available to the public. However, I am employed in the nuclear industry, and I have at times been involved in constructive discussion with local environmental study groups. My experience has convinced me that the general public is capable of making reasoned decisions on environmental problems if all relevant facts are presented in an understandable and unemotional manner.

ENGINEERING PROBLEMS OF FUSION POWER PLANTS

There are several reactions with heavy isotopes of hydrogen which could theoretically be used to generate power. The best prospect for the immediate future seems to be the fusion of deuterium and tritium nuclei; tritium does not occur in nature and must be produced from lithium by bombarding it with neutrons from the reaction. Research in Western Europe has concentrated on the fusion of deuterium-tritium plasmas confined by magnetic fields, with the heat exchanger and radiation shield around the reactor also used as a container for lithium.

Anyone who believes that harnessing the hydrogen bomb for peaceful use will be fundamentally less hazardous than controlling the atomic bomb reaction should consider the findings of Andrew Holmes-Siedle, of the University of Reading. He writes that:

'Gamma rays are generated by the interaction of the neutrons with the structural material. To the materials scientist, these

radiation levels seem unpleasantly large, although not much greater than those experienced near the core of a fission reactor. In the CTR [controlled thermonuclear reactor], however, the demands on components and materials are greater in that a high-vacuum chamber, powerful magnets and numerous other complicated systems have to be operated in this environment, as well as the coolant system.' (3)

The engineering problems of the fusion reactor will be qualitatively similar to those of the fission reactor, and will be greater in magnitude.

THE RISKS ASSOCIATED WITH NUCLEAR FISSION

One frequent contributor on scientific topics to the popular and technical press, and a critic of existing European nuclear power power programmes, Dr. Tom Margerison has identified the hazards of fission reactors as being:

(a) Long-term leakage of liquid and volatile active isotopes during normal operation.
(b) Catastrophic release of liquid and volatile active isotopes following accidents at reactors, processing plants or waste disposal facilities.
(c) Insufficient protection for stores of long-lived solid wastes from spent fuel.
(d) Theft of the basic materials for making atomic weapons by terrorist groups.

Margerison sees the eventual development of fusion power, which he predicts will take about fifty years to become commercially viable, as the most promising solution to these problems (2). It therefore seems reasonable to consider how a possible fusion reactor might meet these four criteria.

POSSIBLE HAZARDS OF THE FUSION REACTION

Dr. W. Häfele of the Kernforschungszentrum, Karlsruhe, and Dr. C. Starr of the Electrical Power Research Institute, Palo Alto, may be quoted as spokesman for the critics of nuclear fusion. It should be mentioned also that Dr. Häfele is associated with the development of the fast breeder fission reactor in Europe; much of his writing is intended to show that the hazards of the fission breeder are not so great as some people believe.

Häfele and Starr point out that the fusion reactor will breed and use tritium, a gaseous radioactive isotope of hydrogen. A reactor of 5000 MW(t) will contain such a large quantity of tritium that the leakage will have to be as low as 0.001% in a year if the dose rate to the general public is to be below the target figure of 1 mrem/year now accepted as realistic for light-water reactors.

This large tritium inventory would be released into the atmosphere if an accident were to breach the reactor's containment, in exactly the same way as radioactive isotopes of iodine would be released after a similar accident in a fission plant. Any reactor would be designed to shut down automatically after such an accident. Häfele and Starr state that 'immediately after shutdown the volatile activity (^{131}I) of the fission core is very much greater than that of the fusion plant (^{3}H), but this is equalised in about a month and after that the fusion volatile activity exceeds the fission.' (4) (this result is due to the long half-life of tritium, which is measured in years, while radioactive iodine decays in a matter of days). They admit that immediate action would be needed to protect the public after an accident to a fission reactor; they cite the Windscale incident in 1957 to justify their claim that administrative action would minimise the public risk in the short term. After a few weeks, however, the consequences of an accident at a fusion reactor would be the more severe of the two cases.

The lithium breeder blankets of fusion reactors will probably be niobium structures; neutron bombardment of the niobium will produce a long-lived ^{94}Nb isotope. While it is true that there will be no solid wastes from the fuel of fusion reactors, the solid wastes from their structures will eventually require the same safeguards as are at present used for the storage of fission products. The principal long-lived by-product of uranium fission is plutonium, and Häfele and Starr assume that 'in a large-scale breeder economy no more plutonium is produced than is consumed.' On this assumption, they suggest that '... on the very long-term basis the niobium activity is 30 or more times that of the plutonium which is subject to disposal.... the storing of ^{94}Nb is obviously a problem that compares with waste storage from fission reactors.' (4)

They also point out that tritium is the basic material for the construction of the fusion (hydrogen) bomb, and presumably will need the same protection against theft as is currently required for plutonium.

Häfele and Starr conclude that '.... only with the post-shutdown heat generation of the fission core, which requires continuous cooling, does the fusion plant have a quantitative but finite advantage ....' and they go on to suggest that:

.... while fusion is qualitatively different from fission, it does not offer radically significant advantages. Both are breeding cycles .... It is essential for the world's energy future that at least one of these systems should be made operable. In view of the advanced state of the fast breeder programme, this must proceed as rapidly as possible .... fusion breeders provide a back-up insurance programme.' (4)

Enthusiasts for the fusion research programmes naturally do not want to see their work reduced to the status of back-up insurance; this challenge has not been left unanswered. Häfele and Starr have been accused of comparing the most optimistic estimates for the effects of the best fission reactors with the most pessimistic predictions for one particular fusion reactor.

On specific points, it is said that Häfele and Starr have ignored the effects of strontium and caesium release in analysing fission reactor accidents, and have not allowed for the dispersal and dilution of tritium releases by winds when assessing the consequences of a fusion reactor failure. Their critics claim that they have under-rated research into other structural materials than niobium (vanadium is one possibility, and would produce insignificant amounts of active waste). They are accused of under-estimating the value of the much lower rate of post-shutdown heat generation than is associated with the fission reactor, and of exaggerating the value of tritium to terrorist groups - no means of triggering a fusion bomb without a fission explosion has yet been discovered. (5)

As a personal comment, I would also suggest that Häfele and Starr may be unrealistic in assuming that prompt and effective action would always be taken by local authorities after an incident at a fission plant. They ignore any such action when discussing accidents to fusion reactors.

SITING OF FUSION POWER STATIONS

The environmental aspects of the siting of generating plants energised from fusion reactors have received less attention than the possible radiological hazards. This may be because there seems to be no spectacular advantage when compared with existing fission reactors. In fact, in current nuclear power stations, the basic needs of site areas and of cooling water supplies to remove waste heat are influenced to a great extent by the non-nuclear components of the system. If demand for land (which, in Europe, is usually already needed for domestic housing, agriculture or recreation) is to be reduced, some redesign of the generating plant is more important than the adoption of a new reactor.

THE CULHAM LABORATORY STUDY

The 'official' U.K.A.E.A. opinion is at present summarised in a report from the Culham Laboratory (6); although written in 1973, this report was not released to the public until the autumn of 1975. It confirms some of Häfele's and Starr's later comments in principle, though it differs in its quantitative estimates. It also suggests that '.... it is not possible to make a meaningful comparison of the hazards of fission and fusion reactors ....' until at least one workable fusion reactor design is available for detailed study. The report makes the positive proposal that active wastes should be stored at the reactor sites, as then '.... the only necessary transport of radioactive material is to supply the initial tritium inventory, and this can be made a very low risk operation.'

I do not think that anyone will disagree with the report's general conclusion that '.... continuing re-appraisals of fusion reactor safety must be an integral part of fusion design to ensure that the necessary safety measures are incorporated as the design proceeds.' (6)

SIGNIFICANCE OF THE ENVIRONMENTAL PROBLEM

Published literature indicates that the radiological hazards of the fusion process, though similar in kind, will probably be appreciably less in magnitude than the hazards of fission reactors. It would be unfortunate if environmentalist objections were to delay the introduction of nuclear fusion, or to abandon research into the D-T reaction in favour of the theoretically safer D-D reaction. It is always possible to point to some new technology which appears to offer greater promise than techniques which are nearly ready for commercial exploitation.

Nevertheless, such critics as Häfele and Starr have done a great service in providing a quantitative analysis of the risks of the fusion process. Their comments may be challenged in detail, but they cannot be ignored. No one can now assume that fusion offers an absolute solution to the radiological problems usually associated with fission reactors.

In this discussion, it is easy to forget that no practical fusion reactor has yet been constructed. Scientific literature is generally optimistic; some authorities predict that a prototype will be operating within a decade. But experience with other forms of advanced technology suggests that the greatest problems are yet to be encountered; they will come when it is time to convert the laboratory prototype into a useful generating system. We can expect a period of popular enthusiasm after the first demonstration of controlled fusion in the relatively near future. This will probably be followed by a corresponding period of disillusion when the construction of the first commercial plant suffers a series of frustrating delays.

Disillusion will bring pressures to abandon the fusion programme and so release funds for even more expensive projects. Opponents of fusion research will then claim that the glowing promises of fusion power are not, apparently, to be fulfilled. The initial cost of extracting deuterium from seawater will mean that there will be no spectacular reduction in the price of electricity. The control of active volatile releases and solid wastes will involve regulations comparable with those for fission reactors. The real improvements, in both fuel economy and radiological safety, which are associated with the deuterium-tritium fusion process will be forgotten.

In a democratic society, the solution to the energy crisis involves the general public as much as it involves the scientists engaged in the research programmes. Minimizing the risks of fusion power may be tending to bias public opinion in favour of the rapid development of fusion reactors. In the longer term, the opponents of the present programme may be able later to exaggerate these risks in an attempt to bias public opinion in the opposite direction. Social responsibility surely means presenting the facts without any distortion so that decisions are taken as a result of informed democratic discussion.

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SOLAR ENERGY: ITS STATUS AND PROSPECTS

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Abstract

There is a clear need for development of alternative energy sources to replace the depleting hydrocarbon fuels on which we depend for 3/4 of our energy. The characteristics that would be desirable of future energy sources are that they be extensive, inexhaustible, widely available and that they present the minimum hazards to health, the environment, and the "quality of life".

Solar energy, as one of the proposed alternatives, is examined here; the principal subprograms are summarized and their present status is described. The state of development of the different solar technologies varies widely from solar heating of buildings that is ready for commercial development to ocean thermal generation of electricity that is in design stages. It is found that several are well enough advanced to be "under-used technologies" and their cost projections under conditions of industrial development are favorable. The time scale for significant contributions from solar energy is, by conservative estimates, 10 years.

Among the proposed alternative energy sources we find that solar energy is unique in its possession of the desired characteristics as well as further important advantages. It therefore seems appropriate that the utilization of solar energy be designated as our highest priority energy development goal.

I. INTRODUCTION

Among the welter of cross currents that compose our growing energy problems, there do appear to be some facts that are not in serious dispute: First, "... there is a real and increasing gap between the present energy production and essentially all projections of future energy requirements in the U.S. ..."(1). More than 75% of present U.S. energy is supplied from conventional oil and natural gas, fuels that are being depleted significantly and cannot long continue to meet our needs (even reasonably reduced needs) (2). Furthermore, these hydrocarbon fuels have great value for other applications such as petrochemicals, fertilizers, etc. The use of all fossil fuels (including the much more abundant coal) also creates a number of hazards and environmental problems in the extraction of the fuels from land or sea, their transportation and combustion. It is therefore clear that major changes are required in our energy practices and a variety of "alternative sources" of energy are being examined as substitutes for the present ones. Also clear is the troublesome fact that the immense size of our energy industries will cause any change to be a slow one so none of these alternative sources can become important in the immediate future.

Nuclear-generated electricity is a newcomer to this scene that is supplying a growing fraction of our energy. But, apart from the controversies over the potential hazards of the plants and fuel, the plants now built or under construction will require through their lifetime a commitment of all the proven U.S. reserves of high-grade uranium ore (3); thus the need for breeder reactors that can utilize nuclear fuels much more effectively.

Besides breeder reactors, the other alternative energy sources receiving serious attention are nuclear fusion, geothermal energy, shale oil and solar energy. The characteristics desired in the possible alternatives are that they (1) provide very large amounts of energy, (2) are inexhaustible, (3) are widely available, and (4) produce the minimum hazards to health and the environment. Solar energy (SE) appears particularly favorable with respect to such desired characteristics: It is obviously inexhaustible for human use, it supplies about 600 times as much energy to the U.S. (48 states) as our total energy consumption, and its use entails minimal (but non-zero) impact on health or the environment. The major uncertainties concern the time scale in which the potentialities of SE can be realized, the selection of the most promising of the SE technologies, and the eventual cost of SE systems.

As with all newly developing energy technologies, there is no large-scale solar industry whose products can be assessed in performance and cost for terrestrial needs. It is therefore necessary to examine the R&D programs to try to appraise the prospects of solar energy.

II. CATEGORIES OF SOLAR R&D

Nearly all of the federal R&D programs are now managed by the new Energy Research and Development Administration (ERDA) although the National Science Foundation still supports small, longer-range programs. ERDA's recently issued National Plan for solar R&D (4) has the various technologies grouped into three major categories, each with its own "subprograms". These are now described briefly and in parentheses are shown the amounts (in millions of dollars) requested for FY 1976 expenditures:

A. Direct Thermal Applications ($23 M)

The two subprograms are (i) heating and cooling of buildings, including water heating and (ii) agricultural and process heat, including crop drying, greenhouses and industrial process heat. This category of demand now consumes 1/4 of all U.S. energy and therefore represents an area of huge potential benefits. It is also the closest to commercial realization and subprogram (i) has the largest expenditure rate within the solar division.

B. Solar Electric Applications ($36.4 M)

(i) Wind Energy Conversion Systems, WECS ($9 M)
This is an old technology that is being modernized to increase unit size and efficiency, and to reduce cost. Studies of wind patterns and direct mechanical drives are also included.

(ii) Solar Photovoltaic Conversion Systems, SPCS ($11.7 M)
This is another established electrical generation technology (in space vehicles) that is being adapted for terrestrial use. The primary requirement is the development of techniques capable of producing greatly increased quantities of arrays at a much-reduced unit cost. Goals include both "on-site" (dispersed) generation and central station generation.

(iii) Solar Thermal Conversion ($13.2 M)
By concentrating sunlight, relatively high temperatures are produced in working fluids that are then used to drive turbo-generators. Such thermodynamic cycles can be made quite efficient in electrical generation or can be used in "total energy" systems that supply useful heat as well as electricity.

(iv) Ocean Thermal Energy Conversion, OTEC ($2.5 M)
This scheme uses turbogenerators driven by a working fluid that is heated by the surface layers of tropical oceans (∿ 25°C) and cooled by the deep layers beneath (∿ 5°C). This is the only scheme that permits continuous operation without interruptions by sun or wind.

C. Fuels from Biomass ($4.9 M)

Biological materials are converted into clean fuels (for purposes such as transportation) and petrochemical substitutes by a variety of methods including thermochemical, biological and combustion processes. The starting materials are agricultural and forest wastes as well as crops of appropriate terrestrial and marine plants grown for this application. The important, closely related program of conversion of urban wastes is in the Conservation Program of ERDA.

In addition to these conversion technologies, R&D is being performed on associated components such as energy storage (thermal, electrical and chemical) and compatibility devices known as "power conditioning" units. Studies are also being made on various socio-technical programs, system integration requirements and the solar data base.

III. CURRENT STATUS

The various sub-programs are at quite different stages of technological development; some are sufficiently established that they represent "under-used technologies":

Category A is not only well-advanced, but in demonstration use in a number of ways. In fact, "... technologies for solar heating are close to the point of commercial application in the United States..." and "... no insoluble technical problem is now foreseen..." for combined heating and cooling (5). Congress has already authorized $60 million for hundreds of demonstration buildings (residential and commercial) in all parts of the country to be equipped with solar heat by 1977 and with combined solar heating and cooling by 1979 (5). Present life-cycle costs for such heating units appear about equal to the cost of electric heat and about twice that of heaters fueled by oil or gas, but the economics are rapidly changing to favor the solar heaters as mass production lowers their costs and fuel costs rise. Large companies are entering this field for the first time. Problems in this area seem to lie with the unfamiliarity of builders, architects and consumers; a condition that will change with the growth of the industry. One unexpected stimulant is coming from three New England electric utilities that are subsidizing the installation of solar water heaters in homes of some of their customers now using electric heating. In another application, one company produces a million tons of salt annually by solar sea water evaporation (6). It has been estimated that by 1990 the overall savings by the direct thermal category could amount to 1.5% of the nation's total energy budget (7, p. II-32).

In the category of direct electrical generation, solar photovoltaic conversion systems (SPCS) and wind energy conversion systems (WECS) are technologically the most advanced. At present, though, the manufacturing capacity of SPCS is insignificant on the scale of terrestrial needs. As a result, the current price of $20/Watt (peak) for SPCS arrays is still far too high for widespread use. For future large-scale applications, one must look to projections of SPCS array prices; such a projection, together with the price history, is shown in Fig. 1 as an "experience curve". The sharp drop in 1974 was the first consequence of new interest in terrestrial systems stimulated by the oil price increases and embargo of 1973. The dashed projection follows the relevant 75% experience curve of the semiconductor device industry. It is noteworthy that the unit price is likely to reach ∿ $1/W around 1985 as a result of nothing more than the assumed growth in demand. In addition, ERDA has launched a large, single SPCS program (8) to provide by 1985 the capability of fabricating 500 MW (peak) of silicon solar arrays annually at a cost of $0.50/W, a figure that is competitive for on-site applications (7, p. VII-B-3).

On a nearer time scale, a variety of intermediate size, on-site SPCS are planned at intermediate capital costs. There are, in addition, a number of other technically promising variations of SPCS that could reduce the cost more rapidly. For example, even the present high-cost cells might be used economically in very small devices with the sunlight focused onto them by inexpensive collecting lenses or mirrors. An illustration of one such system is shown in Fig. 2. Such concentrating schemes, however, must follow the sun and since they use only the "direct" sunlight, they cannot benefit from the "diffuse" light present in the entire sky, particularly on hazy or cloudy days. They appear most favorable, therefore, for regions having generally clear weather.

Wind energy conversion in small units is also well advanced and a 1.25 MWe system was formerly used in Vermont. A newly designed 100 kWe wind conversion facility has been built by NASA (as part of the ERDA effort) to serve as a prototype for future units, several more will be built this fiscal year, and construction of a 1 MWe system will also be started. Favorable areas with high average wind speeds have been identified and a variety of other technical, environmental and societal aspects of WECS are being analyzed. Costs for large-scale systems in mass production are not yet known although they are projected to be competitive (7, p. IV-41). Public acceptance of the large towers necessary may be a problem in developed areas but WECS are compatible with agricultural and other land uses.

Solar thermal conversion is less well developed but in some forms it is conceptually simple. Construction of a test facility with 5MWth capacity is beginning this fiscal year and system analysis of a 10 MWe power plant is being initiated. These are based on a tower-mounted central receiver heated by a large array of heliostatically mounted mirrors as illustrated in Fig. 3. Dispersed collectors are also feasible in principle and are being

explored. One feature of thermal conversion that is unique among the solar options--the generation of high temperatures--will be exploited in a total energy system by use of the rejected heat of the generator for space-or process-heating. On the other hand, this is the one technique that requires cooling water. Costs are essentially unknown for commercial units but some estimates suggest that intermediate load systems will be competitive with fossil fuel plants around 1990 (9, p. 37).

Ocean thermal conversion (OTEC) is in perhaps the earliest stage of development with basic component and system designs still not resolved. The overall practical efficiency of these systems is estimated to be ∿ 2% (10, p. 70) so enormous quantities of water must be processed and heat transfer must be exceptionally good. Optimum plant size of 100 MWe is estimated (11) and the large floating stations needed would be built with shipyard facilities. Possible environmental effects of large numbers of OTEC plants are being examined.

Bioconversion to clean fuels is sufficiently developed that it "... is commercially feasible to a limited extent today, using urban, farm, and forest product wastes..." (9, p. 2). The use of forest residues as fuel is already saving large amounts of energy used by the forest industry; during World War II a significant portion of France's liquid fuel supply consisted of methanol made from wood (4, p. III-29). Energy crops could cover very large land areas and thus compete with other agricultural requirements, but animal wastes and the residues of various existing field crops appear suitable for conversion to fuels with known methods. System studies are still in progress, with demonstration use of such processes a few years off.

Considerable work is being done on a variety of associated problems. The solar insolation (the rate at which solar energy is incident on a horizontal surface) data base is becoming well established (9, p.11; and 7, p. A-I-3,4). Studies of land use have led to the interesting fact that the total present demand for electricity (∿ 1/10 of the total energy) could be met--at 10% conversion efficiency--using an area about 1/10 of that now devoted to roads (12). Further, there is no requirement for land to be used for fuel extraction or refining, or disposal of residues. In built-up areas, however, there are prospects for legal complications over "sun rights" somewhat comparable to water rights questions in irrigrated areas.

Energy storage will become an important requirement for all solar options and is receiving much attention. Thermal storage in water or rocks is quite effective for small systems; for larger ones a variety of more sophisticated options exist but need further development. Electrical sotrage requirements are nearly identical to the electrical utilities load-leveling requirements that are also receiving considerable private effort (13). For large systems the options include advanced batteries, pumped storage (of gas or water) or hydrogen production. The requirements for power conditioning--the conversion from d.c. to a.c. and use of variable levels of generated power--present little technical difficulty but add another element to systems cost.

IV. PERSPECTIVE AND CONCLUSIONS

Any judgements of solar energy as a national resource must be made on the basis of its comparisons with the possible alternatives. In the past, oil and natural gas were such inexpensive alternatives that they came to dominate all others; resource depletion and environmental harm have only recently been widely recognized as serious problems. For the future, the major alternatives in the U.S. are coal (with potential liquid or gaseous fuels derived from it), shale oil, breeder reactors, nuclear fusion and geothermal energy.

At present, geothermal sources are relatively low cost sources of electricity and will probably be used more in spite of their generally polluting effluent. Their numbers are sufficiently limited, however, that they appear to offer only regional benefits (somewhat like hydroelectric sources). Nuclear fusion has great promise for virtually limitless amounts of energy but the scientific feasibility of power generation has not yet been demonstrated, serious engineering problems exist, and economic and environmental questions will be unanswerable for some time. The U.S. breeder reactor program has encountered steadily rising costs, difficult technological problems and growing public opposition because of health and security concerns. The Clinch River demonstration plant operating date has been slipping regularly and it has been estimated that such plants will not be competitive in this century (14).

Although there are very large quantities of shale oil in the US, its recovery is faced with such serious technical and environmental problems that its large scale production is not in sight. Thus coal appears to be likely to be heavily used but it, too, has important disadvantages in extraction, transportation and combustion. A problem receiving growing recognition is that the development of both of these fossil fuels "... imposes large demands for water at the source. Water problems are particularly acute for our most promising oil shale and coal deposits which are in the western areas of the lower 48 states..." (15, p. 32). In addition, all thermal electric systems consume large quantities of cooling water and, except for solar, they add to the heat load in the biosphere.

In seeking to place solar energy in this picture we find that in none of its three major categories is there evidence of major scientific, engineering, or environmental obstacles to successful development, although not every subprogram will necessarily succeed. In fact, still other advantages appear: (i) When complete energy systems are compared, SE is significantly less capital intensive than is generally recognized because it requires no investment for fuel extraction, transportation or refining. For example, the capitalized cost of nuclear fuel is estimated at $200 per kW (11). (ii) For every joule of electrical energy provided this way, three joules of primary fuel energy are saved. (iii) SE is the most widespread energy resource and its technologies provide for energy systems of all scales; the modular nature of several of the types of converters offers a great versatility in system size--at about the same unit energy cost--that cannot be obtained from other energy sources.

The principal deterrents to the use of at least some SE technologies are the lack of the industrial base and the resulting high initial cost of the systems; this cost problem is increased by the need for supplemental energy of conventional types in most parts of the U.S. For these technologies, though, the projections are sufficiently promising that there is every reason to stimulate not only further development but also the necessary commercialization. As was recommended for new energy sources generally, governments should "... act as a catalyst and provide a climate for the private sector to achieve the required goals..." (15, p. 2). There are many precedents for such actions and a wide variety of steps are being considered by federal, state, and local governments to create this climate, e.g., tax incentives of several kinds, interest rate adjustments, zoning and planning actions, and the use of SE in public buildings. The major benefit that results just from the demand growth that can be stimulated by such steps is demonstrated in Fig. 1 for the case of SPCS.

The time scale in which SE can be expected to contribute appreciably to the nation's energy needs has been projected rather cautiously in the ERDA national solar energy plan (4) as shown in Fig. 4. By 1985, with only a normal pace of development, they expect the replacement of $\sim 10^{18}$ joule/yr (10^{15} Btu/yr) of fuel use, an amount that would require about 40 full sized (1000 MW) breeder reactors to match. By the year 2000 this grows to $\sim 10^{19}$j which will be $\sim$7% of all energy used; beyond that the replacement of other sources by SE continues further. The plan also asserts that an accelerated effort could provide "significantly higher levels" of replacement energy.

This prospect of substantial amounts of energy production in as short a time as 10 years is clearly a consequence of the fact that several of the solar technologies are available and nearly ready for widespread exploitation. Their successful application requires only a sufficient commitment to complete their development and reduce their costs. Nevertheless, the ERDA budget request for FY76 contained only $66.7 million for expenditures on all solar programs including support activities; this is about 3% of the ERDA budget, only one of several signs of a rather hesitant attitude to this field. There seems little doubt that American industries, universities, and laboratories could usefully apply a good deal more than these amounts.

There is reason to expect solar R&D budgets to rise in the future. But the enormous promise that solar energy offers--to augmenting our energy supply, to reducing our dependence on imported fuel, to reinvigorating our economy, to rehabilitating our environment--calls for something qualitatively different. These factors add up to a unique capability of solar energy that warrants a national commitment, in both policy and funding, to make the utilization of solar energy our highest priority energy development goal.

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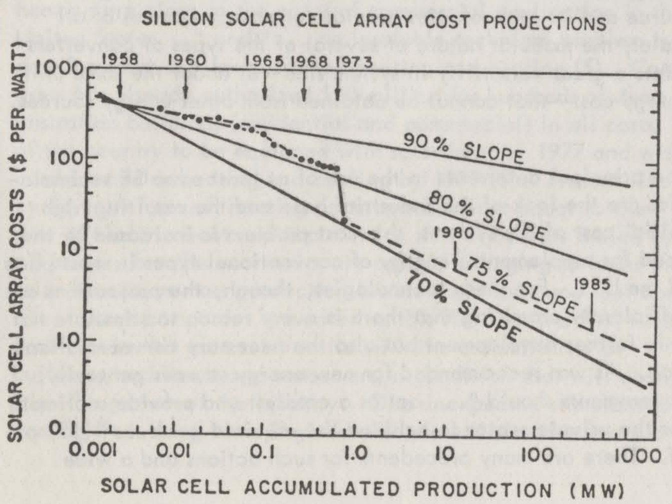


Figure 1: History (solid) and projection (dashed) of the cost of silicon solar cell arrays. The association of fixed production levels with the years 1980 and 1985 are estimates that are dependent on the extent of the commitment made to this technology. (Adapted from Ref. 7, p. VII-C-64)

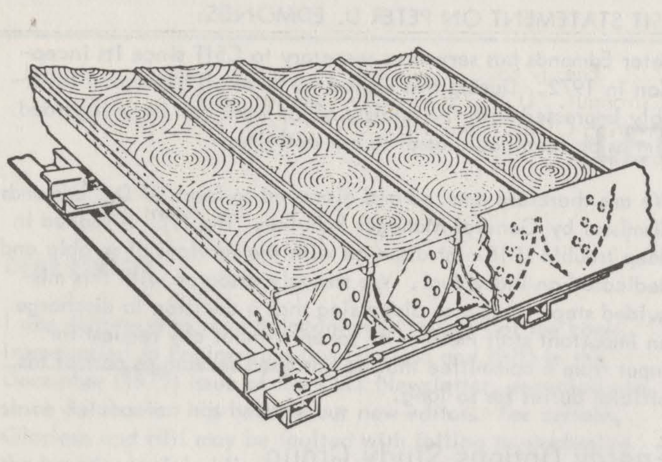


Figure 2: One version of a photovoltaic array using concentrated sunlight on small solar cells. Each set of concentric circles represents a Fresnel lens of molded plastic or glass which focuses the light onto a solar cell about 1000 times smaller in area than the lens. (Courtesy, L. Napoli, RCA Laboratories)

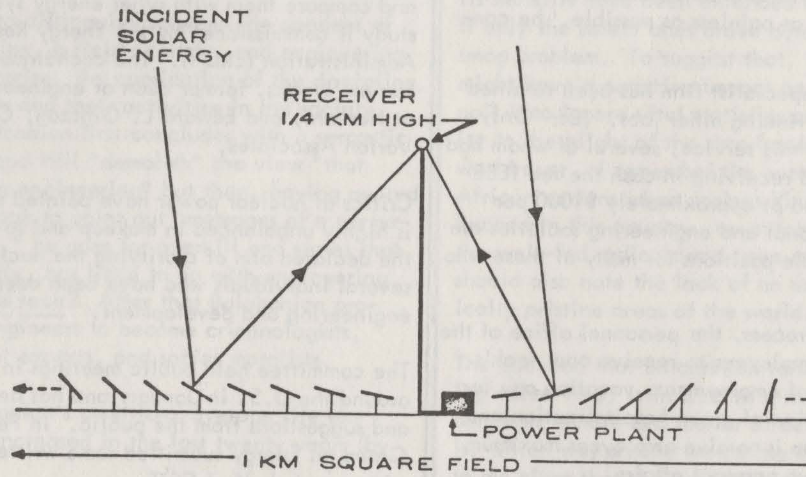


Figure 3: Schematic diagram of a central-receiver type of solar thermal electric converter. A field of sun-tracking mirrors $\sim$1 km^2 is capable of generating nearly 100 MWe during peak sunlight hours.

ESTIMATES OF THE ENERGY AND FUELS TO BE SUPPLIED IN THE U.S. BY SOLAR ENERGY

	1985	2000	2020
DIRECT THERMAL APPLICATIONS (in units of Q=Quads=10^{15} Btu per year)			
Heating and Cooling	0.15Q	2.0 Q	15 Q
Agricultural Applications	0.03	0.6	3
Industrial Applications (Process Heat)	0.02	0.4	2
TOTAL	0.2 Q	3 Q	20 Q
FUELS FROM BIOMASS	0.5 Q	3 Q	10 Q
SOLAR ELECTRIC CAPACITY (in units of thousands of megawatts, GWe)			
Solar Thermal	0.05 GWe	20 GWe	70 GWe
Photovoltaic	0.1	30	80
Wind	1.0	20	60
Ocean Thermal	0.1	10	40
Total Electric Capability	1.3 GWe	80 GWe	250 GWe
Equivalent Fuel Energy	0.07 Q	5 Q	15 Q
OVERALL ENERGY EQUIVALENT IN QUADS	~1Q	~10Q	~45Q
TOTAL PROJECTED U.S. ENERGY DEMAND	100 Q	150 Q	180 Q

Figure 4: Projected solar energy utilization based on normal development rates of the various technologies. The last two lines summarize the projections. (From Ref. 4, page I-4)

NEWS, NOTES, & COMMENT

Resignation of NRC Safety Engineer

Robert D. Pollard, a project manager in the Nuclear Regulatory Commission and chief safety engineer for the nuclear plants at Indian Point, New York, as well as nuclear plants in North and South Carolina and Texas, publicly announced his resignation. He charged that the Indian Point plants were unsafe in design and construction, and were susceptible to accidents that could cause large-scale loss of life and other radiation injuries. He said that he could not "in conscience remain silent about the perils associated with the United States nuclear power program."

[Editor's note: Mr. Pollard is a member of IEEE and an electrical engineering graduate of Syracuse University.]

Resignations of Nuclear Engineering Managers

In February, three managing engineers from the Nuclear Energy Division of the General Electric Company in California publicly resigned their jobs and volunteered to work for the movement supporting the California initiative against nuclear power (see text in this issue). They resigned, they said, because they have come to believe that nuclear energy represented a profound threat to mankind. The engineers -- Gregory C. Minor, Richard B. Hubbard, and Dale G. Bridenbaugh -- are now working against what they had spent most of their professional lives to build.

IEEE LayOffs

The following statement was released by IEEE in early January:

"The Institute of Electrical and Electronics Engineers, in an effort to strengthen its financial position, has found it necessary to reduce the personnel of the headquarters staff by about eight percent. [Ed: closer to nine percent than eight.]

Dr. Herbert A. Schulke, Jr., General Manager, in making the announcement, stated that a general reorganization of the Institute has resulted in the separation of approximately 25 executive and supporting staff members out of a total work force of 288.

'We regret that it has become necessary for the institute to make these changes at the present time,' he said, 'but we are confident that we shall be able to serve our membership in a more efficient and economical manner.'

'In making its decision to cut back, the IEEE Executive Committee, acting for the Board of Directors, specified that every effort must be made to provide those employees leaving our service with all possible financial and personal aid so that the transition to other jobs can be as painless as possible,' he continued.

A professional out-placement specialist firm has been retained by IEEE to assist employees in finding other jobs. [Ed: Only senior employees were offered this service, several of whom had said they would have preferred receiving in cash the fee IEEE paid for this service--estimated at approximately $1000 per person.] Comparable professional and engineering societies are being canvassed to seek suitable positions for many of those who are leaving IEEE.

In overseeing the separation process, the personnel office of the Institute is arranging for all employees to receive one week's severance pay for every year of employment, vacation pay for 1976, and maximum continuation of group hospitalization and other health benefits. The aim is to give employees maximum time to straighten out their own personal affairs.

Mr. Joseph K. Dillard, IEEE president, in commenting on the reduction of personnel, said: 'In a year in which we have raised dues, we cannot possibly operate without a balanced budget. Therefore, this move was inevitable'."

President Dillards's quote in the last paragraph is a non sequitur. The "Therefore" does not follow logically since it fails to take into consideration possible ways of balancing the budget such as resisting the urge to redecorate and refurnish the general manager's suite.

One of the staff members terminated is Dr. Peter D. Edmonds who was Administrator of Technical Services and had been serving as staff person coordinating the activities of a number of IEEE committees, among which was the Committee on Social Implications of Technology.

At its meeting of January 10, 1976, the CSIT authorized its Vice Chairman to make known its sentiments to the Technical Activities Board (of which CSIT is a committee) through a letter. The following statement was submitted to Robert D. Briskman, Vice President of Technical Activities by the Vice Chairman of CSIT.

CSIT STATEMENT ON PETER D. EDMONDS.

Peter Edmonds has served as secretary to CSIT since its inception in 1972. During this period we have all been most favorably impressed with the quality of his work and have regarded him as an invaluable asset to our activity.

We are therefore amazed and dismayed to learn of Dr. Edmonds' dismissal by General Manager Schulke. The IEEE is indeed in deep trouble if it must dispense with the services of so able and dedicated an individual. We strongly disagree with this misguided step. It is also distressing that a decision to discharge an important staff member be taken without any request for input from a committee that he has been serving as part of his official duties for so long.

Energy Options Study Group Formed by NAS

In November 1975 the National Academy of Sciences (NAS) established a 13 member Committee on Nuclear Power and Alternative Energy Systems to "focus on the prospects for various nuclear power options, particularly the breeder reactor, and compare them with other energy systems". The $2 million study is commissioned by the Energy Research and Development Administration (ERDA). The cochairmen of the committee are Harvey Brooks, former dean of engineering and applied science at Harvard, and Edward L. Gintzon, Chairman of the Board of Varian Associates.

Critics of nuclear power have pointed out that the committee is highly unbalanced in makeup and so unlikely to accomplish the declared aim of clarifying the nuclear issues. It includes several individuals who have been deeply involved in nuclear engineering and development.

The committee held public meetings in a number of cities around the U.S. in January and has been soliciting comments and suggestions from the public. In February, the CSIT Study Group on Energy submitted some written comments to the committee on behalf of CSIT.

Another Energy Study Group Formed by Ford Foundation

The Ford Foundation has just formed a study group to make a one-year, $700,000 study of the critical issues surrounding nuclear power. The study will be conducted at the MITRE Corporation under the chairmanship of Spurgeon Keeny, Jr., a former assistant director of the Arms Control and Disarmament Agency. It is said that the members of the "blue-ribbon" study group were chosen partly because they had not taken hard positions on nuclear power issues.

Proposed IEEE Constitutional Amendment

The petition for a ballot to amend the constitution (see letter in this issue) so that voting members would need to approve any increase in dues or assessments has been approved by the Executive Committees of both the Long Island Section and the Cleveland Section of IEEE.

LETTERS

DEAR EDITOR:

I was distressed to read Balabanian's "review" of the book, Introduction to Engineering (by Glorioso and Hill) in the December (1975) issue of the CSIT Newsletter, especially so since Balabanian has become our new editor. For certain, Glorioso and Hill may be faulted with failing to emphasize the broader social obligations of the engineer, and to sensitize their readers to the danger of unexpected and undesirable technological side-effects. But such possible shortcomings hardly deserve the greening broadside in which Balabanian makes false assertions, evidently misrepresents Glorioso and Hill's statements, and overall engages in contradictory and specious reasoning. For instance:

Item: Balabanian fails to distinguish between the concept of engineering as a discipline, a field of study, and engineering as the engineering enterprise, the application of the discipline, which refers to engineers and their activities in the society. Confusing the two, Balabanian first concludes with a sarcastic approval that Glorioso and Hill "demolish" the view "that ideology plays no part in engineering" but then, having quoted extensively from their book to point out "messages of a normative, ideological nature," he goes for overkill and states that "This ideology, incidently, has little to do with engineering as such." Engineering as such? After that Balabanian proceeds with a pitch for engineers to become criminologists, sociologists, management experts, and social moralists.

Item: Contrary to Balabanian's assertion, average life expectancy in the US has increased in the last twenty years (by over a year).

Item: The statement "[a project manager] must ... be prepared to defend his requests for more funds and equipment" reflects to me facts of life, in the USSR and Zambia no less than in the US, and is presumably based on the assumption that the manager believes in what he does and that it is his function to propose new projects and extensions of the current ones. While "building of an empire" is a well known and deplorable tendency of many managers - as well as faculty members - it is unfair of Balabanian to infer that Glorioso and Hill advocate it. I wonder, incidently, when Balabanian last requested a cut in salary.

Item: The statement, "It is very unlikely that our civilization will ever turn around and become less technological: People want comfortable living ..." does not represent to me "the simplistic argument that, unless one 'buys' all advanced technology, one is advocating a return to primitive conditions of life."

Item: The statement, "Frequently an engineer signs an agreement with his company to assign all patent rights to the company" does not imply that he does so clearly as "an independent decision" following the invention rather than as a condition of employment. In fact, "an agreement ... to assign all patent rights" must logically refer to the period prior to the inventions otherwise the engineer would assign the patent rights themselves rather than sign an agreement to do so.

Item: Balabanian's criticism of the effects technology has on health care is an unfair hit and run attack. That many unexpected effects of technology are detrimental to health is obvious and, for certain, smog, use of pesticides, and pollution of all kinds (including verbal) should be vigorously confronted, first of all by engineers. But it is also obvious that most pollution comes about not because technology is overly sophisticated - if anything, one could argue the opposite - but because its benefits have been extended to the broad masses of people. If only the select ones drove automobiles there would be no smog problem. To suggest that, in general, "high technology might have a negative impact on well-care" (italics in original) is to ignore vital statistics and betray a certain insensitivity to the plight of the starving and disease-ridden masses the world over. I remember the outcry in some of the hungry African nations when various kinds of pesticides were being banned in this country: an outcry predictably ignored here by the well-fed radicals and news media alike. Balabanian should also note the lack of an exodus into the still technologically pristine areas of the world.

The question that Balabanian raises, are science and engineering value-free, is in a sense a non-question since what those concepts denote is a matter of definition. The real question is, which way should we define the terms? And here it seems to me clear that the acceptance of an intuitive, Marcusian link between "is" and "ought" can only lead to intolerance and bigotry, to a multiplicity of private truths competing for social power and privileges by the force of arms and inflammatory rhetoric instead of through the democratic processes of consensual validation and the scientific processes of experimental verification and demonstration of superior performance. It is this writer's hope that the vast majority of the scientific community accepts, at least as an ideal to be approximated, the Weberian model dividing the total scientific endeavor into the realm of facts, the value-free science, and the realm of values and ethics, the concerns of the value-laden scientists.

Of course we work in a social context which influences our actions, decisions, preferences, and even "needs". And of course we should examine very carefully the effects of these influences including the effects of technology. But this is a task for us to handle not as scientists in our professional capacity but as scientifically trained citizens; and we should not cease being concerned even when we cease to work as scientists.

Henry R. Novotny
Marina Del Rey, CA

DEAR EDITOR:

The recent Sinclair-Klig exchange on (largely) the philosophy (or lack thereof) of Engineering and Balabanian's review, under the title "Engineering and Ideology", of the Glorioso-Hill book "Introduction to Engineering", both excite one to attempt further articulation on engineering thought.

Sinclair observes, validly, that the philosophy of technology is certainly not a philosophy of engineering and that "one has only to read a typical reference work on the history of technology to realize that the major concern of the historians is with the gadgets and processes which are produced by engineers."

Therein lies a clue: to know about an obsolete gadget or process is, per se, supremely irrelevant to working engineers. Such information is patently dead to all but the keeper of the museum, the collector of relics. That so few historians or would-be historians of technology and of engineering have realized this is probably why today we are lacking in articulation of the philosophy of technology and, especially, the philosophy of engineering.

Balabanian refutes the supposition made by some, that ideology plays no part in engineering; in particular, he finds that Glorioso and Hill demolish that supposition. Interestingly, however, he subsequently qualifies the latter finding with the somewhat contradictory statement (if we are reading the context right): "They (Glorioso-Hill) are advocating a particularly social ideology [which], incidentally, has little to do with engineering as such." Which merely takes us back to square 1!

Herein, perhaps, lies reinforcement to our previous clue: Engineering does not admit a history in the same sense as philosophy or literature do - a clue veiled in an earlier comment by Balabanian that "unlike politics and art, say, science and engineering [have been widely held to be] value-neutral activities." Which again boils down to the fact that an obsolete gadget or process is, per se, patently dead to all but the keeper of the museum.

Out-dated technology and engineering have their own layers of accumulated dust, layers of mummification. Brushing off the layers is not enough of a history. What perhaps is needed is a profound history of ideas, a history of engineering thought, not one of gadgets and processes, not one of engineers themselves, but a history which translates into contemporary language and values the best of the past. It would seem such a history has not yet appeared if we agree (as this writer does) with Sinclair's contention that we do not yet have a philosophy of engineering.

The discussion extends into the educational sector. In response to Klig's suggestion of it, Sinclair contends that a debate on the role of the engineering schools in electrical engineering is meaningless without a philosophy on which to base it.
So be it, modern engineering curriculums have been under heavy criticism in recent years for "swinging too much towards science," for introducing excesses of abstraction, for getting too far away from "what good engineering education used to be like," for neglecting engineering "design" (whatever that may mean.) Certainly, present-day engineering curriculums are poorer in old-fashioned data and facts, and are more abundant in concepts, the belief being to thereby more readily achieve a synthesis and simplification which may bring about far more sweeping changes, and sooner, in response to today's more highly complex and pressing problems, than would an accumulation of facts, data and here-and-now "practical" or "design" experience (necessarily a slow process, always vulnerable to obsolescence). The dichotomy has rallying points on both sides. Which, we contend, simply reinforces both Sinclair's contention and our view on the need for a new history, a history of ideas, not one of gadgets, processes and engineers themselves. The full effects of the more-conceptual learnings of present-day curriculums may well still be in the realm of conjecture, but will not in any case be negligible.

The Glorioso-Hill book appears to deal more with the pragmatic sociological aspects of engineering and its practitioners than with engineering thought in the context in which we have attempted to present it, if we read and interpret Balabanian's review correctly; though we have not read the book itself.

Basil R. Myers
Dean, College of Engineering and Science
University of Maine
Orono, ME

DEAR EDITOR:

Referring to SIT-Two Views, CSIT Newsletter Issue No. 12- It seems that Mr. Klig's seven points should be reclassified as Social Activism within IEEE. I picked up this copy of CSIT Newsletter from a friend hoping to read serious discussions of computer privacy, liason work with the congressional Committee on Technology Assessment, consumer uses of electronics, in general, a future oriented social study of advances in electrical engineering. I find instead some nebulous arguments about philosophies and pension plans.

I did find the other two articles interesting and a great deal more relevant to the title of this Committee than the article referred to above.

If SIT-Two Views is a typical article then I join in Mr. Klig's plea for articles less nebulous, more to the point and more germane to society and electronics.

Michael W. Michalak
Commercial Officer
USA Consulate General
Sydney, Australia

DEAR EDITOR:

The proposed IEEE constitutional amendment accompanying this letter modifies the manner in which dues and assessments can be increased. It is endorsed by the Long Island Professional Activities Committee, and we solicit your support for the measure. If adopted, the amendment would require voting-member approval for any dues or assessment increase, but it would have no effect on the fees for the technical groups. This new arrangement would allow the members to have some say in IEEE fiscal matters in concert with the Board, and thereby strengthen the IEEE.

We ask members who agree with the proposed amendment to help us collect the required number of signatures necessary to place the amendment on this year's ballot. Thank you for your consideration of this matter.

Lawrence Edelman, L.I. PAC Project Director
Robert Bruce, L.I. PAC Chairman

PETITION FOR A BALLOT TO AMEND THE IEEE CONSTITUTION

I (we) the undersigned member(s) of the Institute of Electrical and Electronics Engineers (member grade or above) hereby petition for the following constitutional amendment - to require that the voting members approve all dues increases or assessments prior to adoption - to be placed on a ballot and mailed to all voting members in accordance with Article XIV of the IEEE Constitution.

CONSTITUTIONAL AMENDMENT

SECTION 3 SHALL BE ADDED TO ARTICLE IV

Sec. 3 The dues or assessments of the members shall not be increased without the concurrence of the voting members. This concurrence shall be obtained by placing the proposed increase on the ballot identified in ARTICLE XII Section 4, and fulfilling these requirements:

A simple majority of the ballots cast shall be in favor of the increase;
The total number of ballots cast shall not be less than twenty percent of the total number of voting members.

[Return signed petitions, including printed name, member no., and date, by May 1, 1976 to: Lawrence Edelman, 247 Belmore Avenue, East Islip, NY 11730.]

ETHICS FOR ENGINEERS: A CODE AND ITS SUPPORT

Stephen H. Unger, Columbia University, Dept. of Electrical Engineering and Computer Science

1. INTRODUCTION

A code of professional ethics for engineers should be regarded as a positive factor that defines, encourages, and supports ethical behavior, rather than as a negative factor that outlaws and punishes the unethical.

It can serve as a focal point of resistance to assaults on responsible professional conduct that stem from pressures to meet a deadline, obtain a budget increase, make a sale, win a contract, cut costs, impress a superior, win a promotion, avoid a tough problem, land a job, conceal a blunder or prevail in a technical debate. It can help create a climate in which it is natural to include ethical considerations in decision making.

In order to be meaningful, widely applicable and effective, a code of professional ethics must meet certain conditions. It should be clear and concise so that important concepts are not buried in details and it is not tedious to read. Meaningless generalities and points covered by civil or criminal codes should be omitted. It should be confined to rules directly relevant to professional conduct, with room for application in the light of a variety of general moral codes [1].

In this article a revision of the 1974 IEEE Code of Ethics [2] (see box) is proposed and the problem of making such a code effective is discussed.

IEEE CODE OF ETHICS FOR ENGINEERS

PREAMBLE

Engineers affect the quality of life for all people in our complex technological society. In the pursuit of their profession, therefore, it is vital that engineers conduct their work in an ethical manner so that they merit the confidence of colleagues, employers, clients and the public. This IEEE Code of Ethics is a standard of professional conduct for engineers.

ARTICLE I

Engineers shall maintain high standards of diligence, creativity and productivity, and shall:

1. Accept responsibility for their actions;
2. Be honest and realistic in stating claims or estimates from available data;
3. Undertake engineering tasks and accept responsibility only if qualified by training or experience, or after full disclosure to their employers or clients of pertinent qualifications;
4. Maintain their professional skills at the level of the state of the art, and recognize the importance of current events in their work;
5. Advance the integrity and prestige of the engineering profession by practicing in a dignified manner and for adequate compensation.

ARTICLE II

Engineers shall, in their work:

1. Treat fairly all colleagues and co-workers, regardless of race, religion, sex, age or national origin;
2. Report, publish and disseminate freely information to others, subject to legal and proprietary restraints;
3. Encourage colleagues and co-workers to act in accord with this Code and support them when they do so;
4. Seek, accept and offer honest criticism of work, and properly credit the contributions of others;
5. Support and participate in the activities of their professional societies;
6. Assist colleagues and co-workers in their professional development.

ARTICLE III

Engineers shall, in their relations with employers and clients:

1. Act as faithful agents or trustees for their employers or clients in professional and business matters, provided such actions conform with other parts of this Code;
2. Keep information on the business affairs or technical processes of an employer or client in confidence while employed, and later, until such information is properly released, provided such actions conform with other parts of this Code;
3. Inform their employers, clients, professional societies or public agencies or private agencies of which they are members or to which they may make presentations, of any circumstance that could lead to a conflict of interest;
4. Neither give nor accept, directly or indirectly, any gift, payment or service of more than nominal value to or from those having business relationships with their employers or clients;
5. Assist and advise their employers or clients in anticipating the possible consequences, direct and indirect, immediate or remote, of the projects, work or plans of which they have knowledge.

ARTICLE IV

Engineers shall, in fulfilling their responsibilities to the community:

1. Protect the safety, health and welfare of the public and speak out against abuses in these areas affecting the public interest;
2. Contribute professional advice, as appropriate, to civic, charitable or other non-profit organizations;
3. Seek to extend public knowledge and appreciation of the engineering profession and its achievements.

2. DISCUSSION OF REVISION

A comparison shows that the proposed revision is not a drastic one. The principal effect is an added emphasis on the engineer's responsibility to society. This effect and other improvements are accomplished by:

(a) A reordering of articles which places the paramountcy of the engineer's responsibility to society first;

(b) Rewording some items and the prefaces of some articles;

(c) Deletion of some items or their absorption elsewhere. Deleted items (1974 Code I.5, II.5, and IV.3) pertain to adequate compensation, support of professional societies and extending the public's appreciation of our profession. Desirable as these concepts are, I consider them to be, at best, marginally relevant to ethics. (Item I.1 and I.5 are partly absorbed in the preface of article II.)

(d) The addition of some items. Some of these (proposed I.4, last clause of II.2, and IV.5) do not require comment, but perhaps I.2 does. The intent here is to promulgate the idea that the engineer should try to make the product of his work beneficial to mankind. Since many projects may have a multiplicity of consequences, some good and some bad, and since people of good will may disagree as to where on the good-to-bad scale a particular effect lies, it must be left to the individual to do the evaluation. The point is that a professional does make such assessments rather than blindly follow orders.

3. MAKING THE CODE WORK

In professions such as medicine and law, where most practitioners are self-employed and deal directly with members of the public, the problem of making a code of ethics effective is that

PROPOSED REVISION OF IEEE CODE OF ETHICS FOR ENGINEERS

Preamble

Engineers affect the quality of life for all people in our complex, technological society. It is therefore vital that they pursue their profession in an ethical manner so as to merit the confidence of colleagues, employers, clients and the public. This IEEE Code of Ethics is a standard of professional conduct for engineers.

Article I

Engineers shall regard their responsibility to society as paramount and shall:

1. Inform themselves and others, as appropriate, of the consequences, direct and indirect, immediate and remote of the projects they are involved in;

2. Endeavor to direct their professional skills toward ends they deem, on balance, to be of positive value to humanity; declining to use those skills for purposes they consider, on balance, to conflict with their moral values;

3. Protect the safety, health and welfare of the public; speaking out against abuses of the public interest that they may encounter in the course of professional activities in whatever manner is best calculated to lead to a remedy;

4. Help inform the public about technological developments and the alternatives they make feasible;

5. Contribute professional advice, as appropriate, to worthy non-profit organizations.

Article II

Engineers shall practice their profession in a dignified, responsible manner and shall:

1. Keep their professional skills up to date and be aware of current events that may affect or be affected by their work;

2. Be honest and realistic in stating claims and estimates; never falsifying data;

3. Accurately describe their qualifications for proposed engineering assignments.

Article III

Engineers shall, in their relations with employers and clients:

1. Act as faithful agents or trustees for their employers and clients in business or professional matters, provided such actions conform with other parts of this code;

2. Keep information on the business affairs or technical processes of an employer or client in confidence while employed and later, until such information is properly released, provided such actions conform with other parts of this code;

3. Inform their employers, clients, professional societies or agencies, public or private, of which they are members or to which they may make presentations, of any circumstance that could lead to a conflict of interest;

4. Neither give nor accept, directly or indirectly, any gift, payment or service of more than nominal value to or from those having business relationships with their employers or clients.

Article IV

Engineers shall, in relations with colleagues and co-workers:

1. Seek, accept and offer honest criticism of work, and properly credit the contributions of others;

2. Assist colleagues and co-workers in their professional development and treat them fairly regardless of race, religion, sex, age or national origin;

3. Encourage colleagues and co-workers to act in accord with this Code and support them when they do so;

4. Report, publish and disseminate information freely, subject to legal and proprietary restraints, provided such actions conform with other parts of this Code;

5. Promote safety in work situations.

of setting up procedures for discovering, investigating, judging and penalizing misconduct on the part of practitioners. This is not the case in a profession such as engineering where most practitioners (particularly electrical engineers) are employees.

Here the primary problem is that most engineers do not perceive themselves as being free to adhere strictly to the kind of code under discussion. Such adherence could easily lead to conflicts with their employers followed by unpleasant consequences [3]. Hence a common attitude is to avoid considering the whole matter. Of course some employed engineers do function in conformance with the kind of code under discussion and have been able to survive professionally. The case of the three BART engineers [4] illustrates dramatically the need for new institutions to support employed engineers whose adherence to the code of ethics gets them into trouble with their employers.

Proposals have been made [5-8] to set up procedures somewhat similar to those used to defend academic freedom for university professors, namely attempts at informal mediation and, failing at this, investigation by a small committee, publication of a carefully written report and censure of the institutions found at fault. This has been carried out over the past half century by the AAUP with considerable success. The American Chemical Society (ACS) has, since 1962, been engaged in a somewhat similar activity [9] on behalf of members receiving "unprofessional treatment" from employers.

From at least 1972 through its demise in 1975, the IEEE Ethics and Employment Practices Committee considered various proposals for enforcing the employment guidelines and backing up ethical engineers [6,7]. A copy of the last draft developed by EEPC is included as an appendix to this article.

In response to a CSIT resolution, 3/25/74, calling for the initiation of procedures as outlined here (and for IEEE intervention in the BART case), the IEEE Board of Directors approved of the filing of the amicus curiae brief in the BART case [10] and empowered its Executive Committee to file similar briefs in analogous cases. But it was explicitly stated that IEEE will not take an adversary position in such cases, and no action was taken on setting up support procedures.

CSIT efforts since 1973 to establish a new IEEE award for those who acted to protect the public interest despite personal risk, have not yet succeeded, though the matter is still being pressed.

Serious consideration should be given to proposing legislation that would make explicit the claim made in the BART case amicus curiae brief that an engineer cannot be legally discharged for bona fide efforts to protect the public safety. Such a law would be a valuable tool for the ethical professional.

4. CONCLUSIONS

It is unlikely that any plausible combination of institutions could fully protect an engineer against employer retaliation following a serious collision over a point of ethics. However, it is probable that enough protection could be provided to reduce greatly the bias against ethical behavior. Although short sighted employers will doubtless resist the initiation of such measures, the more perceptive ones will realize that they are better off with engineering staffs composed of responsible, independent-minded professionals.

It is important to minimize the possibility of measures instituted to support ethical engineers being used to the advantage of incompetents and crackpots. Apart from the direct damage that such misuse would cause, it would also serve to discredit the support mechanisms. The procedures outlined here and in the references do not appear to be overly vulnerable to such abuse, and this has not been a serious problem for the AAUP or ACS.

Assuming that support measures are put into effect and that they operate smoothly, their effect would be to create an atmosphere conducive to ethical practice. It would still remain for engineers to exercise their freedom to act as real professionals. Educational programs, carried out as part of engineering curricula as well as by engineering societies would probably have an important positive effect. The role of enforcement programs by ethics committees of professional societies would probably be limited to dealing with relatively small numbers of cases of extreme misbehavior. This is the situation in other professions. However, the fact that engineers tend to practice in closer contact with their peers than is the case with lawyers, doctors, and accountants, would probably lead to more effective restraints on unethical acts.

The desirability of reordering the articles was pointed out to the author by Marc Apter, and Gerald Rabow suggested adding the final qualifying clause of IV.4.

REFERENCES

[1] Unger, "Codes of Engineering Ethics," CSIT Newsletter, 12/73.

[2] "IEEE Code of Ethics," IEEE Spectrum, 2/75.

[3] Vandivier, "The Aircraft Brake Scandal," Harpers Mag., 4/72, pp. 45-52.

[4] Unger, "The BART Case: Ethics and the Employed Engineer," CSIT Newsletter, 9/73.

[5] Paschkis, "Moving Toward Responsible Technology," ASME Paper, 71-WA/AV-1, 1971.

[6] Rivers, "An Enforcement Recommendation for Implementing Employment Standards", Submitted to IEEE Employment Practices Committee, 6/21/72.

[7] Unger, "A Proposal to Support the Ethical Engineer," CSIT Newsletter, 12/73.

[8] Paschkis, "Ethics in Engineering," ASME 75-TS-3, Presented at the Engineering Applications Conference, Balt., MD, 5/18-21/75.

[9] "ASC Steps Up Member Assistance Efforts," Chem. and Eng. News, 1/28/74, p. 29.

[10] "Engineering Ethics: The Amicus Curiae Brief of the IEEE in the BART Case," CSIT Newsletter, 12/75.

APPENDIX

Procedure for protecting the employed engineer who is in jeopardy because of observance of Code of Ethics.

1. A committee headed by a respected IEEE member should be set up to handle cases of this kind (to be referred to as ethics cases in the rest of this document). (It could usefully be the same committee that handles violations of the Guidelines since the ethics cases are likely, sooner or later, to involve such violations.) Legal counsel should be available to this committee. When a claimed ethics case is brought to the attention of any officer or member of the IEEE, it should be referred to this committee.

2. A short, preliminary investigation, probably including an interview with the engineer, should be held to determine whether there really is a case. If it looks as though there is, a waiver should be obtained from the engineer. [See attached form.]

3. Two or more committee members should be delegated to determine the facts of the case. They should interview the engineer, employer (if he is willing), and anyone else whose testimony would be useful, read all relevant documents and submit a written report to the committee.

4. If after reviewing the written report, the committee concludes that there really is no case, the parties concerned are so informed and the case is dropped. If, however, it concludes that the employee is indeed in jeopardy, or has in fact been fired or treated unprofessionally, because of ethical behavior, the employer is so notified. An attempt is made to explain to the employer the specific ethical issues involved in the case, and the importance of ethical behavior in general. Should the employer decide to make redress for any wrongs done, the case is closed.

5. If the committee finds the employer to be clearly in the wrong and he is unwilling to change his behavior (or unwilling even to be interviewed), the action to be taken must be determined together with the engineer. Some possibilities are:

a. The engineer may wish to take no further action, perhaps in the interest of retaining his job. His wishes should be respected.

b. If the committee judges the case to be sufficiently important, and the engineer is willing, a note or an article setting forth the verified facts (including, for example, that the employer refused to be interviewed) could be published in Spectrum.

c. If the employee wishes to take his case to court, the committee may decide to recommend to the governing board that the IEEE submit an amicus curial brief to the court, although, as in the BART Case, the decision as to innocence or guilt will be left to the jury. In this contingency, the committee may, if it is requested, recommend that the IEEE make a low-interest loan to the engineer.

WAIVER LETTER

Committee
IEEE

Gentlemen:

I believe that my professional situation is in jeopardy because of my observance of the Code of Ethics. I respectfully request that I be given an opportunity to explain this matter to the Committee and to solicit the Committee's assistance. Attached is a summary of my problem.

If you agree that my concern seems justified, you may feel free to contact all other individuals or corporate entities concerned insofar as this is necessary to conduct a thorough investigation. I absolve the IEEE, its operating groups, and all individuals associated therewith of any responsibility for the consequences of your study.

Yours truly,

OBSOLETE IDEOLOGY

SCIENCE FINDS ... INDUSTRY APPLIES ... MAN CONFORMS

This was the motto blazoned on the entrance to the 1933 Century of Progress Exposition in Chicago. The guidebook went on to expound at greater length:

> "Science discovers, genius invents, industry applies, and man adapts himself, or is molded by, new things .... Individuals, groups, entire races of men fall into step with ... science and technology."

If it ever made sense in the past, does this ideology of human submission to things have any meaning in the contemporary world? Perhaps a new motto is needed: any suggestions? Here is one.

SCIENCE DISCOVERS ... HUMANITY DECIDES ... TECHNOLOGY CONFORMS

N.B.

THE APPLICATION OF SYSTEMS ENGINEERING TO SOCIETAL PROBLEMS

Gerald Rabow, Chairman, CSIT Working Group on Systems Engineering and Public Technology. This paper is proposed by the author as an IEEE Position paper.

One of the skills that members of the Institute of Electrical and Electronic Engineers (IEEE), and others, have developed is called systems engineering. It includes the understanding of complex interacting assemblages, and design or intervention so that they perform in some desired way. Projects such as landing a man on the moon would be impossible without systems engineering.

Societal problems also require understanding and purposeful intervention, and the question arises as to the possible role of systems engineering in the solution of societal problems. We believe that systems engineering can play an important part in the solution of societal problems. It may well be that the extrapolation of systems engineering to societal problems is the new ingredient that will permit their solutions, where solutions have not been obtained in the past.

We, therefore, outline in this position paper the characteristics of systems engineering which make it applicable to societal problems, some of the difficulties to be overcome, and what officers of IEEE, electrical engineers, related professionals, educators, government officials, and members of the public can do to help bring systems engineering to bear on societal problems.

Definition of Systems Engineering:

Systems engineering is the relation of the goal for a system to the description of component portions of the system, so that the performance of the system can be predicted from the component descriptions (analysis), or that a set of components can be specified which together will yield a system with the desired performance (synthesis). The expression of these relations involves the language of mathematics.

In the case of complex systems, specialists from many different fields are involved. One of the tasks of systems engineering is to communicate with the various specialists, and to translate the systems descriptions into terminology that the specialists understand. Another task is to take the specialized terminology and translate it into the mathematical language required for the system analysis or synthesis.

A system is an assemblage of interacting components. Although systems engineering has in the past been applied primarily to systems of physical and to some extent to biological components, the components may also be economic or social in nature.

A societal system is a system involving a large number of individuals, in which discretional behavior of individuals has a significant effect on system performance. Examples of societal systems are transportation systems, criminal justice systems, health care delivery systems, and educational systems.

Systems Engineering of Societal vs. Physical Systems:

The following differences between societal and physical systems must be recognized when systems engineering is extended to societal systems:

1. The disciplines that must be interfaced will be extended to include social science, political science, psychology, law, etc., in addition to those encountered with purely physical system such as various engineering specialties, physics, chemistry, and mathematics. Since the ability to interface diverse disciplines is one of the basic characterisitics of systems engineering, the diversification of the disciplines to be interfaced is an extension that systems engineering should be readily able to make.

2. The components of societal systems and their interrelation are generally less well understood than those of physical systems. It should be noted that this is a difference of degree rather than a difference in kind, since even physical systems can include components that are imperfectly understood. When understood, societal systems are likely to be more complex than physical systems.

3. With physical systems, the goal for the system is generally given. For societal systems, the goal may not be available explicitly but be imbedded in the system, and its explication is part of the systems engineering task.

Societal and physical systems have in common the need for systems engineering (or something akin to it), if predictable responses to intervention in the system are to be achieved.

Electrical Engineering as a Basis for Societal Systems Engineering:

At the present stage of development, there is not yet a recognized profession of societal systems engineering. The task of societal systems engineering must, therefore, be assumed by related disciplines. Electrical engineering is close to the discipline of societal systems engineering, because the following fields, which are useful in societal system engineering, are encompassed by electrical engineering:

1. Systems engineering of electrical and other physical systems.
2. Control systems and feedback control theory
3. Communications and information.
4. Computer design and applications.
5. The mathematical analysis of large-scale systems, including societal systems.

The Relation of Systems Engineering to Management and Decision Making:

Systems engineering is an activity that is both involved in and yet distinct from management and decision making. As a part of management, which has overall responsibility for a project, systems engineering is held responsible for the completion of a project in that it must manage the various components to exact the required results. In contrast to management, which is not a field of engineering per se, systems engineering by its name implies direct involvement in the field of scientific processes. As a part of decision making, where specific value judgements must be made, systems engineering gathers the various values attributable to differing aspects of a project which must be taken into consideration before a decision is made. In contrast to decision making, systems engineering may at times have to rely upon the decisions made by others with respect to the ultimate goal of a project.

Special Ethics for Societal Systems Engineering:

As with all advances in civilization, the application of societal systems engineering can result in consequences which may not always be correctly foreseen. The very ability to foresee consequences of actions is, however, one of the distinguishing characteristics of systems engineering. It is thus incumbent on societal systems engineers to make clear in every instance the extent to which a societal systems engineering project might fall short of the ideal. This includes any assumptions and uncertainties, all risks and by whom they are incurred, and to what extent any recommendations are experimental.

Recommended Action:

IEEE officers should:

1. Bring the potential of societal systems engineering to the attention of government officials and other potential users, and the general public via the media.

2. Encourage the inclusion of papers and discussions relating to societal systems engineering in IEEE publications and at IEEE meetings.

3. Explore joint action on societal systems engineering with other interested societies.

4. Set up and support a committee to catalog all attempts to apply systems engineering to societal problems, and the outcome of those attempts.

Electrical engineers and related professionals should:

1. Be aware of and make use of systems engineering in their professional work.

2. Look at societal problems with a systems viewpoint, and communicate this viewpoint to others.

3. Seek and offer to apply their talents toward the solution of societal problems, at the local community level or wherever the opportunity presents itself.

Educators should be encouraged to:

1. Teach the systems approach and its applicability to societal problems to all students at all levels, as essential knowledge for a citizen in modern society.

2. Offer programs of study for careers including societal systems engineering.

Government officials should be encouraged to:

1. Make use of systems engineering in solving societal problems, through their personal understanding and/or the services of its practitioners.

2. Support research and education in societal systems engineering, so that we will be able to better solve our societal problems in the future.

Members of the public should be encouraged to:

1. Seek to understand the systems aspects of societal problems.

2. Insist that their representatives adequately use and support systems engineering for solving societal problems.

EXAMPLE

The following is an example of the application of systems engineering to a societal system, namely the school process at Center Elementary School in New Canaan, Connecticut. It came about because Dr. Stephen E. Rubin, who has his doctorate in general systems theory, decided to apply systems skills to reorganize the school when he became its principal in 1965. The systems engineering task in this case consisted of combining elements from the fields of behavioral theory, practical teaching, management, and mathematical analysis so as to satisfy the objectives for the school system. The attempt to thus create an improved school system appears to have been successful.

System Objectives:

The primary system objective was to allow students to learn at their own pace - commensurate with their ability and motivation to learn - yet to maintain human instruction by teachers in a normal classroom setting. Another objective was to better define what the students learned, which among other things would allow better continuity in instruction among students' successive teachers.

Basic System:

The following are the main components of the system developed at Center School:

1. Teaching Objectives: Curriculum areas or "subjects" are broken into a large number of teaching objectives, for example adding and subtracting fractions or solving linear equations.

2. Tests: Associated with each teaching objective is a means of testing whether the student has mastered the teaching objective. These criterion reference tests can take a number of forms, including written test and manipulation of materials.

3. Flow Graph: The teaching objectives are arranged in a directed flow graph, as illustrated in Figure I. In order to begin a particular teaching objective, a student must have passed all directly connected lower objectives.

Teaching theory indicates that the learning of a given teaching objective requires mastery of appropriate prerequisite teaching objectives. The approach used at Center School to both validate this hypothesis and to determine the hierarchical structure of the teaching objectives was to give the criterion reference tests to all the students, then make a statistical analysis of the results. Where it was found that all students who had mastered y also had mastered x, it was assumed that x was a prerequisite to y. From these results, the directed flow graph of Figure I was constructed. Optimum performance of the Center School system depends on the proper construction of the flow graph. If a prerequisite is not recognized and a connection hence omitted from the flow graph, then the teaching of the objective y missing prerequisite x will become more difficult, because the students who are studying y missing x will have to learn x in the process of learning y without this being explicitly recognized. If, on the other hand, prerequisites are assumed and connections put in the flow graph which are not in fact required, then scheduling options are eliminated, and the most effective arrangement of classes and assignments of students to classes may not be achieved.

4. Record Keeping and Scheduling: The results of the criterion reference test serve as the basis for individual histories for each student, which are useful for review of progress by teachers, parents, and students themselves. The current status of each student is used as an input for scheduling classes in the teaching objectives and assigning students to them.

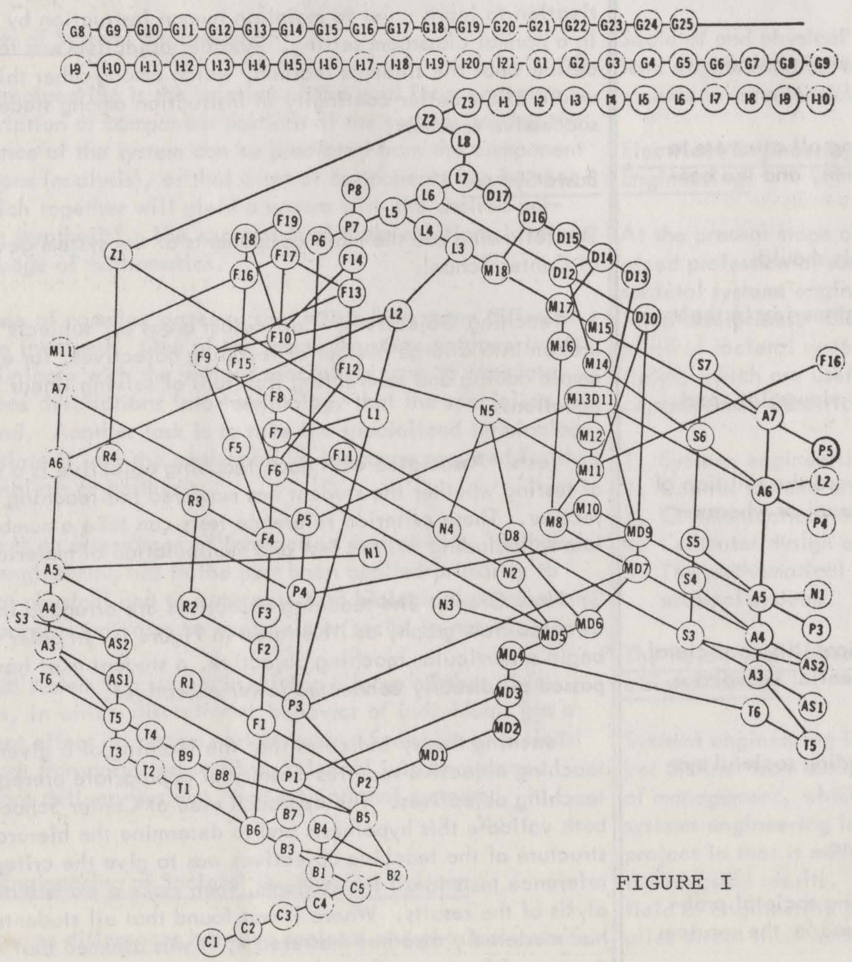
Simultaneous classes in various teaching objectives are scheduled. Each student is assigned to a class for which he is eligible (i.e. has not passed that objective but has passed all prerequisites). At any time that a student appears to have learned a teaching objective, he takes the corresponding test. If he passes the test, he is then assigned to a new class for which he is currently eligible. The teaching objectives which are currently taught are reviewed daily and changed when required. The aim in scheduling is, as much as possible, to have the number of teaching objectives taught at any one time equal to the number of available teachers, with every student being eligible for at least one objective currently being taught, and with classes of reasonable size.

5. Teaching: What all the other components of the system have done is to arrange, generally, to have a teacher, over a period of time, conduct a class in a single teaching objective, to which students come who are in need of this objective. The students join the class when they are ready, and leave the class - individually - when they have mastered the teaching objective. The teacher can cope with the differences in progress toward attainment of the objective among his students, because the range of the subject (a single teaching objective) is much smaller than it is in conventional classes.

System Performance:

As far as can presently be judged, the Center School system appears to be a success. Students appear to achieve at higher than conventional levels, with some sixth graders learning high school algebra. The school is behaving like an overall system rather than a bunch of individual classrooms. Most teachers, students, and parents seem to like it. An ultimate judgement of the Center School system can probably only be made after controlled tests following its successful replication elsewhere.

[The CSIT Newsletter invites readers to comment on this paper.]



MATHEMATICAL OBJECTIVES
Integrated Flow Chart
Center School, New Canaan, Ct.

TERMINAL	TERMINAL
(C) The counting numbers	(N) Numeration & number theory
(B) Add & subtract, 0 - 9	(F) Fractions
(P) Place value, including exponential notation	(L) Decimals
(T) Ten & teen facts	(R) Ratio & proportion
(A) Addition, 2 digit nos.	(Z) Percent
(S) Subtraction, 2 digit nos.	(I) Integers
(M) Multiplication	(G) Algebra
(D) Division	

Graphics by Herbert Jennings

FIGURE I

SYSTEMS ENGINEERING AND SOCIETY'S PROBLEMS

Carl Barus, Dept. of Engineering, Swarthmore College

It has been suggested that systems engineering offers a new and effective route to the solution of societal problems, and it has been accordingly proposed* that IEEE and others should therefore advocate the use of systems engineering as a social tool--perhaps even present it as a social breakthrough. There is no doubt that systems engineering has something to contribute to a variety of social-technological dilemmas such as we now face. Yet I believe it is misleading to elevate the systems concept to the status of a social breakthrough.

Systems engineering is a body of technique. Although first applied to weapons systems, it can be brought to bear on certain aspects of a broad class of problems--including social problems. But it cannot encompass all aspects of any significant problem--not even that of landing a man on the moon.

It is illusory to think of a set of techniques as a means to social progress or a cure for long-accumulated social ills. This is not to say that systems engineering has no place in social planning; it is only to plead that we recognize the limitations of systems engineering as well as the complex nature and origins of society's problems. Such problems are rarely "solved" in the engineering sense. (is even BART, for example, a solution? Only in the sense that it exists.) The danger is that we shall place too much faith in the systems approach (a kind of "technological fix") and thus overlook key factors not amenable to those techniques.

The phrase "societal problems" lumps together an enormous variety of human concerns. Is a "transportation system" a societal problem? If so, why not the Apollo program? Is a "criminal justice system" a societal problem? An "educational system"? (Quoted examples are from the Proposal). If so, why not poverty? Urban decay? Why not alienation of youth? Why not the "rat-race" syndrome that so many junior and middle-level engineers complain of?

What is the difference between "societal" problems and social problems? The dictionary offers no help here. One clue may be that I, at least, feel more comfortable with "societal" when talking to some professional colleagues. "Social" sounds a bit soft-nosed and perhaps even left-leaning. Maybe poverty should be considered a social problem, and transportation a societal one. But where does that leave housing, for example?

Social problems have roots. They have causes somewhere in the body politic, past and present. Transportation systems (societal?) and moon-landing systems (technical?) are involved in many ways with these roots, not least so through the network of social and political priorities that society's leaders design, inadvertently or otherwise. (Try applying systems engineering to that real-world political system!)

If we can re-define social problems as "societal"--or merely shift attention from problems like poverty to problems like transportation, we can successfully avoid coming to grips with the social problems of the real world. And there are always some among the political and economic leadership who would prefer to do exactly that. For them, systems engineering may be a valuable tool indeed.

The fact is that in real life the existence of social conditions disadvantageous to some is often perceived by others as a positive benefit. High unemployment, for example, operates to reduce the bargaining power of labor unions and thus to reduce labor costs in industry. High unemployment is also seen by some as a means of stemming inflation. Similarly, rising crime rates tend to benefit those who seek to institute authoritarian measures of social control. International tensions are notoriously effective in stimulating military R & D and procurement, with profound effects (beneficial to many) on the nation's economy.

Are unemployment, crime and impending war social problems? Societal problems? If so, can systems engineering help us "solve" them? The answer is that it cannot--because there is no agreement as to what would constitute a solution.

Admittedly the above examples are rather overwhelming and perhaps too much to expect of systems engineering at its present stage of development. I consider briefly, therefore, the educational system (Center Elementary School, New Canaan, Connecticut) described in some detail in an addendum to the Proposal. Specifically, the mathematics curriculum at the school has been laid out in flow-graph form with the nodes of the graph representing "teaching objectives" (e.g. adding fractions). There are some 170 such nodes in the curriculum, starting with counting and going as far as algebra. Each node also represents a teaching class in which the pupil remains until he or she has mastered that teaching objective.

At least one elementary educator I know is critical of this engineered educational system as sketched in the Proposal. It is designed around the cognitive aspects of elementary education and appears to ignore the affective aspects. It would seem to foster premature competitiveness. The rapidly shifting pattern of class membership would hinder the formation of enduring friendships among pupils and trusting relationships between pupil and teacher.

Just what societal problem does this educational-system design "solve"? It will not end debate (I sincerely trust) among educators as to how elementary mathematics should be taught, and certainly not that as to how various kinds of early school experiences affect children's personality growth. While the school's program may be successful in a number of ways and for a number of reasons, it is not clear that systems engineering is either a necessary or sufficient condition for any such successes.

What seems to have been engineered is essentially a system for manipulating a set of counters (pupils) so as to maximize a set of indices (test scores, etc.). It seems rather more like a bookkeeping system than a school. Yet the logic of the system design appears relentless: the purpose of a mathematics curriculum is to teach mathematics. Therefore maximize the test-score/cost ratio.

* G. Rabow, "Proposed IEEE Position Paper: The Application of Systems Engineering to Societal Problems," (hereinafter called "the Proposal"). See pp 28-30 of this issue.

The trouble is that we really don't know the purpose of compulsory schooling itself, or even that of teaching mathematics, seemingly a noncontroversial part of it. Is it to prepare young people to fill places in the existing economic machinery? Is it to produce a wise electorate, capable of supervising a government "of the people, by the people and for the people"? Is it to inculcate respect for knowledge, truth and beauty? Respect for authority? Is it to prepare the coming generation for loving parenthood? Or for war? Is it to show the novice that life and learning can be fun?

The Proposal makes an interesting statement with regard to these questions: "For societal systems, the goal may not be available explicitly but be imbedded in the system, and its explication is part of the systems engineering task." (My emphasis.) The first part of this does seem to be the case with the educational system sketched. The goal is "imbedded" as a tacit given: maximize test scores. Given the system, the goal is not only imbedded but buried in a welter of detail couched in technical jargon. Although the details are open to debate and refinement, there seems little reason to expect the designers to "explicate" the goal or any but the most persistent critics to question it.

The difficulty is that most of the societal systems we perceive as such are in reality subsystems. An elementary mathematics curriculum is a subsystem of a school, which in turn is a subsystem of a community and of the larger educational system up through the universities. The educational system itself is effectively a component of an economic system and of other systems which might be said to make up "society as a whole."

A goal of systems engineering is optimization. This goal requires specification of performance criteria. But if such criteria can be specified for a subsystem, it implies that the system itself is already designed in the large, a proposition which many would dispute. Many Americans, for example, believe the Apollo program (a subsystem) to be a misapplication of taxpayers' money. The same goes for the Interstate Highway subsystem, the nuclear-power subsystem, the Vietnam war subsystem, and many others. For these dissenters, the claim that such a subsystem has been "optimized" (or will be) only adds insult to injury.

Can any system or subsystem be optimized? Only with respect to specified performance criteria, which as the Proposal recognizes, are ultimately value judgements. But the Proposal adds "systems engineering may at times have to rely on the decisions made by others with respect to the ultimate goal of a project." This frankly puts the systems engineer in a subservient position. Should a professional society like IEEE promote such a downgrading of its members?

Obviously decisions must be made. Action must be taken. But "society's" decisions are political ones. If IEEE, or other elite groups, can convince the public that systems engineering (or Big Brother or the Court Magician or the Oracle or the divinely-appointed King) knows best, then democracy is in trouble.

In sum, preoccupation with the systems-engineering approach at best carries with it the risk that we shall fail to perceive the true nature of the "societal problem" at hand. At worst, systems engineering can become a tool by which various holders of economic and political power can define "societal problems" and "solutions" in such a way as to suit their own private interests rather than those of the general public.

Engineering Ethics Conference

A conference on engineering ethics was held in Baltimore on May 18-19, 1975, cosponsored by units of seven professional societies, including IEEE. A number of case studies were reviewed in which engineers have confronted conflicts between the requirements of their employment and their ethical concern for the public welfare. Educational approaches toward greater awareness of ethical concerns and avenues for expressing such concerns -- both during professional training and afterwards -- were discussed. Codes of Ethics, their improvement, implementation, and enforcement were also discussed. Further information can be obtained from:

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