Principal Hazards of Nuclear Power and its Alternatives

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The nuclear issue has blossomed into a grass roots national debate. The escalating political battle over nuclear power has been marked by a proliferation of petitions, polls, and statements purporting to reveal what the nation's scientists and engineers -- those supposedly in the best position to judge the merits of the issue -- really think about the controversial technology.

Each side is actively trying to line up special interest groups. The pro-nuclear people have been focusing on Engineering Societies (IEEE, Am. Inst. of Chem. Eng., Health Physics Society, Am. Nuclear Soc., Nat. Soc. of Professional Engineers), trade unions and labor organizations (principally the Electrical Workers), women's groups (AAUW and the League of Women Voters). The opponents have lines up the National Council of Churches, Common Cause, the N.Y. chapter of the American Institute of Architects, etc. The pro-nuclear fraction is purportedly putting together a $7 million war chest.

The nuclear issue is on the ballot in numerous states, principally in the west. The California Initiative to be voted up or down in June, is undoubtedly the most significant of these.

Thus, at its present stage of nuclear debate is a political battle analogous to the presidential primaries. A vote in California will be closely watched, but, like the presidential primaries, the outcome in California will not determine the future of nuclear power in the U.S.

At this stage it is impossible to predict the political future of nuclear power in the U.S. The debates are not limited to the U.S. There is growing opposition in Sweden, U.K., France, W. Germany, the Netherlands, Australia, New Zealand, and Japan. As with the U.S. the future of nuclear energy world-wide is a wide open issue.

With this introduction I want to begin with two basic premises: (1) our society obtains great benefits from electrical energy, and (2) in the United States we waste an enormous amount of energy, a large share of which is electrically generated. The first premise is not an argument for the current or an increased rate of energy consumption in the United States. We consume some 36 percent of the nonrenewable energy resources of the world. We also consume roughly the same percentage of the world's depletable natural resources. According to Robert McNamara of the World Bank some 900 million people subsist on less than about $40/year. Taking a global view I submit there is no evidence from our recent history that increasing the rate of energy consumption in the industrialized west is going to do anything but increase the spread between the rich and the poor and increase the total number of poor. It is the Third World countries, not the big energy consuming nations, who have been hit hardest by the recent increases in oil prices. A continued exponential growth in our depletion of natural resources in my opinion will only make the present situation worse. It is immoral.

Our energy choices have traditionally rested on a series of self-fulfilling prophecies - forecasts based on correlation, not causality. The arguments for a greater rate of energy consumption in the United States is that economic growth measures by the gross national product is coupled to energy growth and economic growth means more jobs and a better standard of living. Russell Train, head of EPA, recently wrote in *Science*, "Our standard of living has continued to rise at the same time that we have become increasingly less satisfied with the quality and character of our lives." As Dennis Hayes notes such a paradox might lead a sensible person to question the standard being applied. The standard of course is summarized in the Gross National Product. It is, as Mr. Train suggests, obvious that the quality of our lives can diminish as GNP swells. We can increase GNP by eliminating speed limits on highways. This would increase the accident rate, which in turn would increase car sales, and hospital and motruary expenses, thus increasing GNP, particularly GNP/capita. Energy consumption would also increase. Stated in another way by Amory Lovins, "we are learning, increasingly and irreversibly, that many of the things we have been counting as benefits of affluence are really remedial costs, incurred in the pursuit of unstated, intangible benefits which might be obtainable in other ways without these costs.[1/]

1/ Amory B. Lovins, Pinkham Notch, New Hampshire, 1 June 1975, Introduction to Nonnuclear Futures by Amory B. Lovins and John H. Price, reprinted from "Not Man Apart," mid-July 1975, p.3.

A number of recent studies, including those by the Ford Foundation's Energy Policy Project (Ford - EPP), the Council on Environmental Quality, and the Environmental Protection Agency, indicate that energy and economic growth can be decoupled and even suggest that labor and energy are properly viewed as alternative factors of production. As the Ford-EPP study indicated:

> *. . . the fear of the ripple effect of economic disruption and lost jobs, if we do not continue high rates of energy growth, is unfounded. This fear confuses the impact of sudden supply disruptions with the quite different longer term effects of a slowdown in the growth of energy demand by way of economically efficient energy conservation.*2/

Energy conservation is a loose and somewhat unfortunate term that indicates both (1) improving the efficiency with which energy is produced, transported, and consumed, and (2) reducing the historic rate of growth in the consumption of energy demanding services. The Ford-EPP study concluded:

> *. . . that it is economically effecient, as well as technically possible, over the next 25 years, to cut rates of energy growth at least in half. Energy consumption levels could be 40 to 50 percent lower than continued historical growth rates would produce, at a very moderate cost in GNP - scarcely 4 percent below the cumulative total under historical growth in the year 2000, but still more than twice the level of 1975.*3/

2/ *A Time To Choose, America's Energy Future*, Energy Policy Project of the Ford Foundation, 1974, p.132.

3/ *Ibid.*, p.136.

In *A Case for Energy Conservation*, Dennis Hayes notes that more than one-half of the current U.S. energy budget is waste. Hayes goes further than the Ford-EPP study arguing that for the next quarter century the United States could meet *all* its new energy needs simply by improving the effeciency of existing uses. These conclusions rest upon conservative assumptions. They assume that lifestyles will change only cosmetically -- that Americans will continue to travel as many miles, keep their homes just as warm, operate as many appliances, and eat what they now eat.

Numerous studies have demonstrated that saving energy is nearly always cheaper than increasing supply.

In the Ford-EPP study it was shown that under conservative economic assumptions that the U.S. could afford to spend, on "technical fixes" to save energy, about $200 billion initially plus $200 million a day - and that would still cost less than increasing supply by the amount which would otherwise be projected.[4/]

Switching now to a third premise -- there is no such thing as a free lunch -- none of our current energy sources are free of environmental, social, or economic dangers. Therefore, if and when an additional unit of electrical capacity can be justified, the benefits and risks of nuclear power must be judged against those of other alternatives. For base load electrical energy generation the principal fuels presently available are natural gas, oil, coal and uranium.

4/ Lovins, *op. cit.*, p.4.

Natural gas is in short supply. One of the major sources of world tension stems from the international oil economy. Both oil and natural gas have more efficient alternate uses as fuels. For these and a variety of other reasons, the U.S. should discourage the use of oil and natural gas as a fuel for generation of electricity except in existing plants in urban environments.

Without significant improvements in the technology of mining and burning of coal, coal is not an acceptable alternative. The social costs are quite high. The present way we mine coal is criminal. Without the addition of stringent control technology the health effects and property damage from sulfur and nitrogen oxide emissions is thought to be quite high. Although modern particulate control equipment can remove up to 99.7% by mass of the particulate emissions, the removal efficiency drops off for particles below 2 microns in size. Little is known about the health effects of fine particulates; it may be that some of the health effects ascribed to sulfur oxides and nitrogen oxides are in fact the result of fine particulate emissions. The only real solution to these social costs is to gasify the coal. This is an expensive alternative. The particulate and CO_2 emissions from burning fossil fuels may result in climatic changes on a global scale. We have already increased the amount of CO_2 in the atmosphere by about 10 percent and we have burned only a few percent of the world's estimated resources of recoverable fuels. By the year 2000, it is estimated that we will have increased the CO_2 level in the atmosphere by another 10-20 percent.[5/]

5/ Frank vonHippel, "A perspective on the debate," *Bulletin of the Atomic Scientist*, September 1975, p.38.

Particulates may be a more serious problem. The role of man's activities in causing climatic change is not established because of the tremendous feed-back effects which are not well understood. The social cost of burning fossil fuel could be enormous if a significant impact on world agriculture occurred resulting in famine.

Reliance on nuclear power is also not an acceptable alternative for reasons I will now discuss in some depth.

Looking back to the 1960's and the early 1970's, the environmental debate relating to electrical energy production centered on the health effects due to routine releases of radioactivity from the nuclear power industry compared to the various insults of the coal technology. Fortunately, routine releases from the nuclear industry are amenable to technological fixes. For example, the allowable releases of radioactivity from nuclear power plants have been reduced to the point that hardly anyone thinks that issue is worth his time anymore. Consequently, the nuclear debate has shifted to what I call the unscheduled events, specifically those related to:

- The diversion of nuclear fuel, particularly plutonium, from the fuel cycle, either by criminal elements within a country for use in the manufacture of weapons of mass destruction or as a matter of national policy by a country employing nuclear power for the production of energy but wishing to obtain national nuclear weapons capability;

- The potentially catastrophic releases of plutonium and nuclear wastes from accidents or deliberate disruption of a nuclear power plant, a fuel reprocessing plant, a waste storage facility, or during transportation between these elements of the fuel cycle.
- The necessity for perpetual, reliable containment of the nuclear wastes for many generations into the future.

As an introduction, let me say many of us believe the first category -- the risks associated with the diversion of nuclear fuel -- are not amenable to technical resolution. Were it not for deliberate acts of sabotage, the second category of events -- catastrophic accidents at nuclear facilities -- would be amenable to technical resolution. Unfortunately, with respect to these there is no valid scientific basis today for calculating the likelihood, or maximum long-term effects, of these catastrophic events in order to demonstrate that the risks have been reduced to an acceptable level.

The third concern -- the necessity for perpetual, reliable containment of the high level radioactive nuclear waste -- may be amenable to technical resolution. Technical solutions, however, are often lost through institutional and political failures. No credible high level waste solution has been or can be reliably demonstrated and, for reasons that are more political and institutional than technical, I have no confidence that the radioactive waste management problem will be resolved in an acceptable manner on a world-wide basis in the foreseeable future. The waste management problem raises the fundamental ethical question of our rights to leave the countless future generations a permanent heritage of radioactive products. It highlights the fact that the fundamental nuclear issues are not technical but social, and ethical. In a democracy such issues should be resolved only through the political process.

I will not discuss each of these three issues in more detail beginning with the diversion problem.

The Safeguards Problem

The global spread of nuclear weapons capability is on the verge of running out of control.

The United States, the Soviet Union, France, West Germany, Canada and Japan are the principle nations locked in a fierce competition to sell nuclear power reactors to less developed countries (LDCs). U.S. exports of reactors, related equipment and uranium enrichment services are expected to approach $1.1 billion in 1976.[6/]

These reactors are of questionable value in meeting the energy requirements of the LDCs, but they are the source of a by-product material, plutonium, that can provide any nation that wants it, the atomic bomb.

6/ *Forbes*, April 15, 1976, p.93.

Today, there are about 200 reactors in the world, which have generated about 20,000 kilograms of plutonium -- enough for about 2,000 atomic bombs. By 1985, the world's 800 reactors will have generated 700,000 kilograms of plutonium, the material for 70,000 bombs.*/ By the year 2000, nuclear power reactors will be producing between 1 and 2 million pounds of plutonium *annually* according to various estimates.

Fortunately, most of the plutonium from power reactors has not yet been separated from the spent fuel of these reactors. The spent fuel is highly radioactive and is virtually inaccessible, except for possible terrorist acts of sabotage.*/

Once the spent fuel is processed in a heavily shielded plant, however, the separated plutonium is easily managed in small, sealed containers. It is also extremely toxic,*/ making it suitable for dispersal devices in amounts too small to make a nuclear explosive.*/

The commercial justification for separating the highly toxic and explosive plutonium is to recycle it into power reactors as a fuel, thereby conserving uranium and reducing nuclear fuel costs. If breeder reactors are developed for widespread commercial use, they will generate more plutonium than they consume, thereby introducing even larger quantities of plutonium in the nuclear fuel cycle than would be produced by the current generation of light water and heavy water reactors.

Problem Exports

France and Germany, over the apparent objections of the United States,*/ are now preparing to export plutonium reprocessing plants to Pakistan and Brazil. South Korea also tried to purchase a reprocessing plant from France. Germany's agreement with Brazil is for an entire nuclear industry, including a uranium enrichment plant -- another facility that produces atomic bomb material, in this case highly enriched uranium.

These transactions represent the first crack in the nonproliferation dam -- the first exports of nuclear fuel facilities (as distinguished from reactors) to non-nuclear weapons nations. India demonstrated last year with its underground nuclear explosion what it could do with plutonium from a small reprocessing plant that the Indians built by themselves.

Pakistan and Brazil, like India, have not ratified the Nuclear Non-Proliferation Treaty (NPT). South Korea recently ratified the NPT, to ensure continued supply of nuclear reactors and fuel from the United States, but it can drop out of the Treaty with only three months notice and then be free to use its peaceful plutonium stockpile for weapons purposes. Approximately 1000 pounds of plutonium, enough fissionable material to fabricate 100 atomic bombs, have accumulated to date at India's Tarapur reactors and are under Indian guard and control, subject to inspections and measurements by the IAEA.

"Peaceful Uses"

The plutonium used in India's explosion came from a Canadian reactor and was to be used, according to an Indian-Canadian agreement, for peaceful purposes. The agreement does not specifically bar explosions, and India ignored a Canadian letter that sought to define peaceful uses as meaning no explosion.

The United States also has "peaceful uses" agreements with 30 nations that do not specifically bar explosions. The State Department is now seeking to renegotiate these agreements to bar explosions, and is apparently encountering resistance from some of the recipient nations.*/

Inadequate International Controls

The Nuclear Non-Proliferation Treaty prohibits nuclear explosions, peaceful or otherwise, by non-nuclear weapons states, and it designates the International Atmoic Energy Agency to administer safeguards needed to "detect and thereby deter"*/ the diversion of nuclear materials for weapons purposes.

The NPT-IAEA system of safeguards controls has been subjected to increasing criticism.*/ It is incomplete: three of the six nuclear weapons nations have not ratified the NPT (France, China and India), and some 20 non-nuclear weapons nations are outside the Treaty, including several insecure or unstable nations which are suspected of having weapons intentions (Pakistan, Brazil, Argentina, Taiwan, South Africa, Egypt, Israel and Spain). Half of the nations which presently have enough plutonium in their spent fuel to produce one or more atomic bombs have not taken the NPT pledge against developing their own nuclear explosives.

The NPT-IAEA safeguards system is also limited by the fact that it is based on nationsl nuclear materials accounting systems. IAEA inspectors take crude measurements to verify the plutonium and uranium inventories as kept by the nations themselves. There are only now about 40 IAEA inspectors to monitor 60 major facilities in 60 countries, and the inspectors tend to be from less-advanced nuclear nations and to lack the sophistication of the nuclear experts whose activities they have to monitor. An international safeguard system based on national recordkeeping has been viewed critically over the years.*/

IAEA safeguards, whatever they are worth, do not extend to certain nuclear facilities in non-NPT countries, including such weapons-sensitive facilities as India's reprocessing plant, South Africa's uranium enrichment plant, and reactors in Spain and Israel. Individual nuclear exports to non-NPT nations are now covered by IAEA safeguards, but these safeguards are less rigorous than those applied to NPT nations.

Furthermore, non-NPT nations are free to develop their own nuclear technology, based on the expertise they develop through their imports, and then to build their own indigenous nuclear facilities outside of IAEA safeguards.*/

The various loopholes and inadequacies make the NPT-IAEA safeguard system clearly inadequate to the task of preventing the world-wide spread of nuclear weapons. No sanctions were imposed on India. International safeguards are nothing more than a paper deterrent.

Nuclear Terrorism

The danger of a nuclear-proliferated world is only partially attributable to nations. The greater danger perhaps is from nuclear terrorism -- possible acts of sabotage, theft and nuclear blackmail. The task of fashioning crude nuclear devices is generally conceded to be within the capability of increasingly sophisticated and well-organized terrorist and criminal organizations, assuming they can obtain the required amounts of plutonium or enriched uranium.

The increasing amounts of nuclear materials that will be generated by power reactors, and the present trend toward processing and storing these materials nationally in widely dispersed facilities, serve to increase the vulnerability of the world nuclear power industry to terrorist acts. It will be impossible to prevent the diversion of small (20 lb.) quantities of plutonium from the hundreds of tons that will be generated by, and recycled into nuclear reactors annually by the 1980's.

I want to turn now to domestic safeguards. During 1973 and 1974 a number of reports were published that were highly critical of existing domestic safeguards. Prominent among these were two GAO reports, the report of the Ford Energy Policy Project by Willrich and Taylor, and the AEC's Special Safeguards Study known as the Rosenbaum Report.[7-10/]

Prodded by these reports the AEC modified its safeguard regulations in 1974. However, the Rosenbaum Report, published after the regulations were changed, concluded with the following:

> *Even though safeguard regulations have just been revised and strengthened, we feel that [the] new regulations are inadequate and that immediate steps should be taken to greatly strengthen the protection of special nuclear materials. We hope that this paper will contribute in a positive way to the speedy implementation of such steps.*

In an expression of its concern, the U.S. Congress, in the Energy Reorganization Act of 1974, mandated that the newly created Nuclear Regulatory Commission undertake a one year study of safeguards. This study, called the Security Agency Study, is nearing completion.

Late last year, after undergoing classification review, the reports of numerous NRC safeguards consultants were made public. These reports were critical of existing domestic safeguards and have served to heighten our concern over existing domestic safeguards. These reports and other information have convinced me that the possibility that plutonium or other similar materials now hend by companies under NRC licenses might be stolen and fabricated into a

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7/ U.S. General Accounting Office, *Improvements Needed in the Program for the Protection of Special Nuclear Material*, (November 7, 1973).

8/ U.S. General Accounting Office, *Protecting Special Nuclear Material in Transit: Improvements Made and Existing Problems*, (April 12, 1974).

9/ Willrich and Taylor, *Nuclear Theft: Risks and Safeguards* (1974).

10/ U.S. Atomic Energy Commission, *Special Safeguards Study ("Rosenbaum Report")*, (April 29, 1974).

nuclear bomb is real. Terrorist activity and other forms of anti-social violence are an almost daily occurrence. In an age of organized crime, of terrorists bombings, the risks of nuclear theft, blackmail and terrorism cannot be dismissed. From 1968 through 1975 there were 99 reported threats and acts of violence directed against licensed nuclear facilities in the U.S.,[11/] 76 threats and acts of violence directed against unlicensed nuclear facilities, and 28 threats and acts of violence involving nuclear materials.[12/]

Some 14 or so private facilities around the country are licensed to, and do, possess and ship plutonium and other nuclear bomb materials. Although most of these facilities are tied to national defense, they produce highly enriched uranium fuel for naval reactors.

In late January of this year NRDC obtained two internal NRC documents. One of these was a memorandum, dated January 19, 1976, by Carl H. Builder, Director of the NRC's Division of Safeguards. In it, Builder conceded that he was "not in a position to judge current safeguards [against nuclear theft] as adequate or inadequate." The Builder memorandum went much further however. It stated:

> *I am concerned that some or even many of our currently licensed facilities may not have safeguards which are adequate against the lowest levels of design threat we are considering in GESMO (which are 'for an internal [employee] threat, one person and, for an external threat, three persons).*

In short, the head of the NRC's safeguards program is stating that he doubts that the safeguards employed at some or even

11/ Letter to James M. Cubie, Public Citizen, dated January 19, 1976, from John G. Davis, U.S. Nuclear Regulatory Commission.

12/ Letter to James M. Cubie, Public Citizen, dated January 26, 1976 from H. E. Lyon, U.S. Energy Research and Development Administration.

many licensed facilities are adequate to prevent plutonium or similar materials from being stolen even when only small efforts are involved, such as a theft attempt by one employee or three armed intruders. This small threat of 1 to 3 individuals must be compared with the credible threat or more prudently the maximum credible threat. These threats are discussed in the other NRC document, the Draft Executive Summary of the Security Agency Study:

> *Congressional concern for adequate safeguards was heightened as a result of a special safeguards study done for the Atomic Energy Commission in 1974. That study, by David Rosenbaum and others, . . . expressed concern about the adequacy of protection afforded SNM by the private industrial security systems of licensees. One aspect of concern was the level of threat to facilities and SNM. The authors postulated a maximum credible threat consisting of 15 highly trained men, three of whom might be "insiders," employed by the licensee target firm.*
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> * * *
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> *To estimate the credible threat, the office of Nuclear Materials Safety and Safeguards researched 19 relevant studies and conducted 9 interviews with individuals and groups of professional analysts from the FBI, the intelligence community, the Department of Defense and State and local law enforcement agencies.*
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> *What emerged from this was a consensus estimate that an external threat group will probably number about 6-8 persons and very likely not exceed 12 persons.*
>
> . . .
>
> [A] *credible internal threat, for safeguards purposes, is estimated to consist of 2-3 persons in collusion.*

Given threats of this size, it must be seriously questioned whether *any* of the facilities which are licensed to possess and transport plutonium and highly enriched uranium are adequately safeguarded. Present regulations require two guards armed with pistols. These two guards could be confronted by 6 to 15 commandoes armed with automatic weapons, grenades and bazookas. Moreover, one or both of the guards could be part of the attacking force.

Besides inadequate numbers of guards relative to the threat, the Executive Summary of the Security Agency Study and the various consultant reports point out other serious problems. For example, one of the consultant reports, that of the U.S. Marshals' Service, begins with this statement:[13/]

> *'The image of security is all that's wanted.' This quotation from a study entitled* *Private Security and the Public Interest* *effectively illustrates one problem with guard forces employed by the private sector of the nuclear industry throughout the United States: too often the image has little substance behind it.*

We conclude that this is no idle statement, because the Marshals' report also states:

> *[T]he writers of this report have only considered private guards in nuclear facilities. The generalizations are based upon research, extensive discussions with private security executives, and actual on-site observation of guards at selected nuclear facilities.*

Another consultant, Mr. Charles Brennan, former Assistant Director of the FBI for Domestic Intelligence, recently stated:[14/]

13/ U.S. Marshals' Service, *Security of Special Nuclear Materials*, (October, 1975).

14/ *U.S. News and World Report*, February 16, 1976, p.50.

> *The safeguards are a joke. The companies involved are interested mostly in saving money. They're doing only the bare minimum of security required by the Nuclear Regulatory Commission.*

These conclusions by Brennan and the U.S. Marshals are borne out by the revelation this week[15/] that the workers handling bomb-grade uranium in a plant in Erwin, Tennessee, worked under an "honor system," and were not searched when leaving the working areas where the uranium was kept.

I doubt that an adequate domestic safeguards system is possible short of turning nuclear facilities into armed camps.

But more importantly, the proposed response by the industry and the NRC to the threat of nuclear terrorism goes far beyond simply providing *more* physical security. The nature of the proposed safeguards is a drastic increase in police powers and a concomitant decrease in civil liberties and personal privacy.

I would like to highlight just a few of the civil liberty, privacy and right-to-work issues that are covered in a Harvard Civil Liberties Law Review article by Russel Ayres. First the safeguards program contemplates security clearances for the employees of the nuclear industry. At best, such clearances infringe upon the privacy of the individual being cleared and his family and friends; at the worst they are instruments of suppression and reprisal. In addition to these security clearances, it is also proposed that the employees be given yearly psychological profile tests.

15/ John F. Fialka, *Washington Star*, February 24, 1976, p.1. Based on a report by Barbara Newman, National Public Radio.

Such tests are as insidious as security clearances and a recent report of the Congressional Committee on Government Operations recommended:[16/]

> *It is the recommendation of the committee that the use of polygraphs and similar devices be discontinued by all Government agencies for all purposes.*
>
> *Even if the committee adopted the position of some agencies that the polygraph is useful solely as a secondary investigative technique and that the results of a polygraph examination alone are never considered conclusive, the committee finds that the inherent chilling affect upon individuals subjected to such examinations clearly outweighs any purported benefit to the investigative function of the agency.*

The safeguards plans also call for intelligence gathering to determine potential terrorists and terrorist groups and it was reported that the Texas State Policy were collecting dossiers on anti-nuclear individuals and groups in that state, supposedly for this reason. Such intimidation has a stifling effect on dissent and debate which are essential in a free society. How much governmental investigation into the private lives of its citizens can a free society tolerate? The actions of the Texas State Police and the recent congressional investigations concerning Watergate and the CIA, FBI, and IRS demonstrate that, even at their present level, these investigative powers are abused.

16/ Committee on Government Operations, *The Use of Polygraphs and Similar Devices by Federal Agencies,"* House Report No.94-795, January 28, 1976, p.46.

Because of the threat posed by stolen plutonium, recovery operations can be expected to be severe and involve no-knock search, search without warrant, area search, and detention and interrogation without warrant. In the presence of a nuclear blackmail threat, martial law seems likely.

All of this must inevitably be put under the direction and control of a central agency which would maintain close liaison with state and local law enforcement agencies and those of foreign nations. The FBI has just suspended its plans for a regional computer center whose purpose was to expedite the exchange of information among state and local law enforcement agencies. The reason given was that this would be close to the creation of a federal policy force. This central agency would be a federal policy force and one with expanded powers.

While today we can comtemplate putting checks and restraints on federal investigative agencies, banning polygraphs and holding firm against a federal police force, it is important to realize that in the presence of nuclear blackmail and terrorism these restraints would have to be removed and these breaches of our civil liberties would become essential.

In summary, our reservations regarding the effectiveness of future safeguards stem from the unprecedented and ultimately unworkable demands that will be placed on any future safeguards system and the people working within it. This system would have to operate on a vast, worldwide basis, yet there is no reason to believe that international cooperation on the scale required is possible. It would have to protect against both theft and sabotage both at fixed sites and

and in interstate and international transportation. It would have to be essentially infallible, maintaining what Alvin Weinberg has called "unaccustomed vigilance" and "meticulous attention to detail." And it would have to do so for long periods and in the face of -- not a machine -- but a determined, intelligent and well-financed opposition. Yet we know that our human institutions and those who act within them are far from infallible.

Now I want to turn to the second issue: whether catastrophic events, such as might occur at a nuclear power plant, can be demonstrated to be acceptably low and the debate over whether U.S. water moderated commercial nuclear reactors are safe. There are two approaches to safety analysis where, as with nuclear reactors, the historical record is inadequate to demonstrate that the system can operate with the required degree of safety.

The first is based on the judgment of experienced professionals to determine if adequate design precautions have been taken, and adequate operational procedures are followed. This judgmental review procedure is embodied in the nuclear industries engineering and licensing review procedure used in the construction, licensing, and operation of reactors. Despite this extensive review procedure, the short operating history of nuclear plants, characterized by the liteny of abnormal events, the ECCS controversy, the fuel densification problems, pipe creaks and core vibrations, the Fermi partial core meltdown, Dresden incidences in the early 1970's, and most recently the great candle light jamboree at Brown's Ferry, has been less than satisfactory with respect to plant safety.

The second approach to safety assessments is to use probability analysis techniques. Hence the debate has centered in the recent past around a) the AEC's Draft Reactor Safety Study, commonly known as WASH-1400, or the Rasmussen Report; b) the American Physical Society's (APS) Reactor Safety Study; and c) a series of reports by Henry W. Kendall and co-workers at the Union of Concerned Scientists, including reviews of the Rasmussen Report and the APS Reactor Safety Study.

With respect to the Rasmussen Report there are two important issues that need to be addressed. First, the issue of whether the report is technically correct with respect to estimates of reactor accident probabilities and consequences, and second to what extent the Rasmussen Study is relevant to the broader issue of acceptability of nuclear power even if it were free from technical flaws.

In addressing the first issue it is useful to discuss separately the estimates of accident probabilities and consequences. The assumptions underlying the estimates of health effects and property damage in the first draft of the Rasmussen Report were frequently in error and in other cases somewhat arbitrary. Where errors were made in virtually every case the errors biased the health effects and property damage estimates downward. The Rasmussen study group frequently mis-read the National Academy of Sciences BEIR Report, and ignored latent cancers associated with the selective deposition of radio-nuclides via inhalation and deposition in critical organs (other than the whole body); *i.e.*, bone cancers from Strontium-90.

The same criticisms were made independently by the EPA, the AEC Regulatory Staff, the APS Study Group, and the Union of Concerned Scientists. The consensus was that the Rasmussen Report underestimated the health effects by a factor something on the order of 10 to 25. Judging by the type of errors that were made I have concluded that the Draft was written in haste with a fair amount of incompetence.

The assessment of reactor accident probabilities comprises the bulk of the Rasmussen Report. The validity of this portion of the study depends critically on first, ones confidence that the study group has identified all *important* accident sequences and second, on ones confidence in the determination of the absolute probabilities of each sequence. It is one thing to say as the Rasmussen Report does, that "the methods used to develop the [probability] estimates are based on those developed by the Department of Defense and the National Aeronautics and Space Administration." It is quite another thing to say that the application of these methods to complex systems under human control has been validated by DOD and NASA. The latter, in fact, has not been done. It has not been done by anyone to my knowledge. In fact, the evidence I have seen from NASA and DOD is quite to the contrary. Based on a fair amount of personal experience at model building and predicting events using models of complex systems under human control I have no confidence that all the important reactor accident sequences have been identified. My personal view coincides with the conclusions of the APS review group, namely that:

> *It is difficult to quantify accurately the probability that any accident-initiating event might occur. Many aspects need to be better understood through experience and research before such calculations are tractable . . . we recognize that the [RSS methodology] can have merit in highlighting relative* [original emphasis] *strengths and weaknesses of reactor systems, particularly through comparison of different sequences of reactor behavior. However, based on our experience with problems of this nature involving very low probabilities we do not now have confidence in the presently calculated absolute values of the probabilities of the various branches.*

The final report is now out, it suffers from the same biases and self-serving assumptions as the draft.

In summary, I reject the Rasmussen Report as a meaningful assessment of probabilities and consequences of reactor accidents.

I want to turn next to the second point raised earlier -- the relevance of the Rasmussen Study to the broader issue of nuclear power even if it were free from technical flaws.

First, it is important to note that the Rasmussen Study deals with only two specific reactor types, the BWR and the PWR, -- one size and design of each. In this regard, it is perhaps worth noting here that

Furthermore, the nalaysis focuses on what is only a part of the uranium fuel cycle, whereas the risks relevant to the broader issue are of course the risks associated with the entire cycle. Finally, the Rasmussen analysis is limited to four classes of reactor accidents that most easily assessed, namely those derived from random failure of engineering components, oversight in design, human error in operating the reactor and acts of God, such as tornados, earthquakes, and floods. A fifth class of accidents -- those caused by deliberate human acts are excluded. Inclusion of this class can only increase the probabilities associated with a given level of consequence.

In summary, while it would narrow the debate, even if the Rasmussen Study were freed from its technical flaws, and came to essentially the same conclusion, it would not demonstrate the acceptability of nuclear power.

The Radioactive Waste Problem

I turn now to the radioactive waste management problem. The nuclear establishment categorizes the radioactive residuals from the nuclear industry as low-, intermediate-, and high-level radioactive waste, according to the activity per unit mass of material, that is, the amount of radioactivity per gram. Historically, because of their much higher specific activity, the high-level wastes have been of most concern and have received the most attention. More recently, some observers are beginning to reassess the relative significance of the intermediate and low level wastes. I will discuss first the high level waste problem.

High-level Waste

These wastes are characterized as being small in volume, very long lasting, highly radioactive, and biologically active. If they escape into the environment, they find their way into the air, into the water, and into food chains. There is no recourse other than to isolate them from the biosphere. These wastes are a mixture of fission products and transuranics which are fission by-products. The fission products in general have shorter toxic lives than the fission by-products. The most troublesome of the fission products, strontium-90 and cesium-137, have half-lives of about 30 years. Since a rough rule of thumb is that radioactive wastes whould be stored for a period of about 20 half-lives for the more hazardous radioactive components of the wastes, storage for about 600 to 1000 years is required in the case of fission product wastes.

The fission by-products, on the other hand, are generally radioactive for much longer periods than the fission products. For instance, plutonium-239 has a half-life of over 24,000 years. This means that radioactive wastes that are contaminated with plutonium have to be contained for a period approaching one-half million years.

It is important to remember that although the two broad types of waste, fission products and by-products, are conceptually distinguishable, current and proposed commercial spent fuel reprocessing does not physically separate them. Thus, all the high-level waste must be contained for a period of time on the order of half a million years. There are theoretical proposals for separating out the by-products and "burning" them in fusion reactors or advanced breeders.

Unfortunately, these proposals are exactly that -- theoretical. Even were fusion reactors or advanced breeders available -- and at present they are not -- it is by no means clear that they could be safely or effectively used to destroy fission wastes. Furthermore, at present there is strong industrial sentiment in favor of converting the high-level waste to a realtively insoluble glass soon after reprocessing in order to minimize spread of contamination. It will be virtually impossible to economically reprocess this vitrified waste to separate the fission by-products. Thus, if large amounts of unfractionated wastes are converted to glass before the technical feasibility of this process is proven, it will be economically prohibitive to implement. To dismiss the issue of management of fission wastes by arguing that they can be burned in fusion reactors may be interesting speculation but it is irresponsible public policy.

The times during which radioaotive wastes must remain secure from the biosphere have no parallel in human affairs. Institutional arrangements do not exist and never have existed to guarantee the monitoring of or attendance upon storage facilities over a millennium. In the range of one-half million years, serious geological uncertainties arise. The last ice age was only about 18,000 years ago.

Under existing regulations the high-level radioactive waste recovered from the spent reactor fuel rods can be stored as a liquid at the fuel reprocessing plant for 5 years after which it must be solidified. Within 10 years it must be shipped to the federal repository for permanent disposal. The only problem is there are no operating reprocessing plants and no federal repository. There is no back end to the nuclear fuel cycle ~~Consequently,~~ We call it more appropriately the rear end of the nuclear fuel cycle because it has become constipated. The

The utilities, having no place to send the spent fuel, are storing it on site. Their spent fuel storage pools are filling up, and they are taking stopgap measures to keep from having to shut down for lack of storage space.

There have been four false starts at managing high-level radioactive wastes in the 30 year history of the nuclear program.

First, there is the military waste. Nearly all of the accumulated high-level wastes in this country were generated during the production of plutonium for nuclear weapons or in R&D programs of the AEC in the past 30 years. Most of these wastes are stored on an interim basis in underground tanks at three principal ERDA facilities, the Hanford Reservation near Richland, Washington; the Idaho National Engineering Laboratory near Idaho Falls, Idaho; and the Savannah River Plant near Aiken, South Carolina. The following table summarizes the volumes and the physical state -- liquid or solid -- of the high-level waste in 1975.

High-Level Radioactive Wastes*
(millions of gallons)

Site	Liquids	Solids
Hanford	29.6	27.2
INEL	2.2	0.3
SRP	10.9	8.7
	42.7	36.2

Most of the high-level wastes are now being stored in liquid form. Many of the tanks have leaked, over 500,000 gallons in all. The most

*/ Hearings on ERDA Authorizing Legislation FY 1976 before the Subcommittee on Legislation of the Jt. Comm. on Atomic Energy, 94th Cong., 1st Sess., at 1937(1975).

notable case was in the spring of 1973 when 115,000 gallons of high-level waste leaked from a tank at Hanford over a 51 day period. Although the level in the tank was recorded each day, no one compared the readings.

Everyone involved -- the regulatory agencies, the nuclear industry, and the critics -- agrees that liquid storage is not acceptable. Several techniques of solidification have been demonstrated and the military waste is being solidified. It will be required at civilian reprocessing plants. The issue is not whether or not the wastes should be solidified, and converted to the most nearly insoluble form possible; the issue is where these solid wastes will be placed to assure their isolation from the biosphere for hundreds of thousands of years.

The second false start was an abandoned salt mine at Lyons, Kansas. This was the AEC's first attempt at a federal repository, a permanent disposal site, for commercially generated high-level waste.

> After "substantial" investigation, the AEC in 1971 decided to begin a demonstration project at the Lyons mine. It was claimed before the Joint Committee on Atomic Energy that all the necessary studies for confirming the mine's suitability had been completed. Subsequent to the Congressional budget hearings, the final environmental statement on the proposed demonstration project baldly asserted:
>
> > "By establishing this facility, radioactive wastes of the type previously described [including high-level wastes] will be permanently isolated from man's biosphere, thus providing a direct and lasting benefit to the environment. No significant impact on the environment resulting from the construction or operation of the proposed repository is anticipated."*

* AEC, *Radioactive Waste Repository, Lyons, Kansas*, WASH-1503, p. 2 (June 1971).

Citizens, scientists, private organizations, and state officials in Kansas, however, argued vehemently that the Lyons site had not been adequately proven and that additional studies were required. Now it appears that those scientists and citizens were right and the AEC wrong, for the AEC concluded after further study that the Lyons site is unsuitable:

> "In the course of the investigation, we found that there were several technical problems that had to do with Lyons itself, but not with other salt—the fact that right next door there was another mine that decided it was going to start solution mining. We were only 1,800 feet underground away from the other mine. *Solution mining could well have broken through.* One thing you cannot have is water in to dissolve the salt, because then the salt is no good. That is the thing that made Lyons no good."* (emphasis added).

Thus, even after over 15 years of study of the suitability of salt mine disposal in general and several years of investigation at the Lyons site in particular, a potentially serious failure in judgment occurred. It is questionable whether or not the AEC would have appreciated the potential hazards involved with the Lyons site if the citizens of Kansas had not spoken out.**

The government's next plan and third false start was another interim solution. The AEC announced in 1972 that it would build a Retrievable Surface Storage Facility (RSSF) which was to be a suitable for a period of about 100 years.

The proposal to rely on an RSSF, as well as the AEC's environmental statement defending it, met with substantial criticism. The U.S. Environmental Protection Agency gave the statement the Agency's lowest rating ("Inadequate"), and observed that "the AEC has reversed the importance of the overall program (with its primary goal being the development of a [permanent] disposal method) and the decision to construct a centralized Retrievable Surface Storage Facility (RSSF) (only one of the several feasible interim storage methods)." NRDC strongly supported EPA's objections, and urged the new Energy Research and Development Administration to discard the AEC's draft and re-evaluate the government's entire waste management program.

In April 1975, ERDA agreed (1) to withdraw its congressional funding request for the RSSF and (2) to write a new environmental statement analyzing its plans for handling waste from the time the spent fuel rods emerge from the reactor.

ERDA is supposed to issue some ERDA "Alternative Technologies Report" that will analyze the technical feasibility of all potential methods of handling the radioactive wastes generated by nuclear power plants. After the Lyons fiasco ERDA started examining a salt deposit near Carlsbad, New Mexico. A favorable site was selected by the staff at Oak Ridge National Laboratory. About a year ago the project management was shifted to Sandia Laboratories. After two test holes, ERDA wanted to begin mining. Sandia insisted on a third test hole. It was drilled and it hit a brine solution containing hydrogen

* Dr. Frank K. Pittman, Director of AEC's Waste Management and Transportation Division, *Hearings before a Subcommittee of the Committee on Appropriation*. House of Representatives, 93rd Congress, 1st Session, Part 4, Atomic Energy Commission, page 172 (April 5, 1973).

** A good review of the events surrounding the Lyons, Kansas, affair can be found in the June 1971 issue of the *Bulletin of Atomic Scientists*. See also, William W. Hambleton, "The Unsolved Problem of Nuclear Wastes," *Technology Review*, March/April 1973, pp. 15-19.

sulfide and methane. At Sandia's recommendation the site has been dropped -- the fourth false start -- and Sandia is now looking at the same deposit only about 5-8 kilometers away.

The ERDA budget (operating costs) for high-level waste terminal storage R&D has been increased from $4.6 million in FY 1976 to $33.7 million for FY 1977. This program now provides for concurrent investigations in multiple geographic locations and in differing geologic formations. Presumably, if we have false start number five, we can quickly fall back on options 6, 7, and 8.

The fact ramains there is as yet no high-level waste storage site. There is not even an acceptable proposal for such a storage site. This is particularly disturbing since the existence and severity of the waste storage problem has been known since the first days of the nuclear age and there has been thirty years of study and policy review. The restrained language of a prestigious international scientific body, assembled at the 23rd PUGWASH Conference in 1973 is still valid today:

> "No general solution for the isolation of long-lived radioactive wastes from the biosphere, necessary for many thousands of years, is yet in hand. That is, despite a wide variety of proposals, 'experts' still disagree on whether any of them will suffice. . . . It is impossible to be complacent about expansion in the use of nuclear power without having a solution in hand."

Low- and Intermediate-level Waste

The low and intermediate-level radioactive wastes are characterized as being much larger in volume but far less concentrated, *i.e.*, less activity per unit in volume, than the high-level wastes.

With respect to the low- and intermediate-level waste, the National Academy of Sciences' Committee on Geologic Aspects of Radioactive Waste Disposal, after visiting two AEC affiliates, Hanford and NRTS, concluded in 1960 that they were "still concerned about disposals into seepage pits" and "neither location has been shown to provide safe and permanent disposal." In May 1966, the Committee concluded:

The Committee thinks that the current practices of disposing of intermediate and low-level liquid wastes and all manner of solid wastes directly into the ground above or in the fresh-water zones, although momentarily safe, will lead in the long run to a serious fouling of man's environment. Such methods represent a concept of easy disposal that has had and will continue to have great appeal to operators, but we fear that continuation of the practices eventually will create hazards that will be extremely difficult and expensive to eliminate. Although the ion-exchange capabilities of natural earth materials under disposal sites will retain quantities of radionuclides and provide a safe container for the shorter-lived ones, it would appear to be prudent to reserve a large portion of the capacity for accidental releases -- especially in humid regions where the water table is shallow and distances between disposal sites and discharge points are small.

This report was suppressed by the AEC until about 1970 when Senator Church forced its release.

One of the commercial burial sites which would have been of obvious concern to the NAS was Maxey Flats, near Moorehead, Kentucky. It was licensed by the AEC in 1963. The public was told that it would take over 1000 years for the plutonium to migrate off site. Even as late as 1974 the AEC was saying:

"Chemical and physical characteristics of plutonium (the principal transuranium element) are such that migration in soil or groundwater is unlikely. Deep well samples taken at the perimeter of the burial sites have not shown any detectable plutonium, thus indicating that the buried plutonium has remained immobile." (From USAEC announcement of proposed rule-making on disposal of transuranium-contaminated wastes.) [3]

And even today people like my friend Alvin Weinberg refer to the Oklo geologic phenomena, or the so-called natural nuclear reactor found in the subsurface of the jungles of Gabon, "that most of the fission products seem to have stayed put over 1800 Myr."

The pro-nuclear faction is fond of stating that this natural reactor has great relevance to present-day waste disposal problems. With 2 billion years of hindsight I submit it is not difficult to find a stable geological deposit. Where foresight is required the AEC has failed. In 1974 the Kentucky Department for Human Resources discovered that plutonium was migrating off site at Maxey Flats. Similar off site contamination was found at the Nuclear Fuel Services facility in New York. It was supposed to take over 1000 years; it took less than 12. EPA now says that commercial waste burial of low- and intermediate- radioactive waste should be treated as delayed releases.

Off site migration of radioactive materials at the Beatty, Nevada burial ground was even swifter. The NRC announced in March of 1976 that between 1967 and 1973 site workers had been regularly helping themselves to contaiminated tools and building materials of many kinds. It was reported that residents of the town were appealed to for the return of the items and told there would be no prosecution. Piles of the stuff were turned in.

In every environmental report or environmental impact statement on a nuclear reactor, the applicant or the NRC Staff purports to demonstrate that the benefits of the reactor are greater than the risks and therefore the project is justified. It is well known that benefit-cost analysis is not designed to make judgments about the fair distribution of economic well-being, between people living in the present or between people living in different generations of time. Benefit-cost analysis makes sense only if there is equity; if the same people assume the benefits and the risks. It cannot decide for us whether it is just or fair for the present to impose upon the future the burdens of essentially perpetual care of highly poisonous materials. As economist Allen Kneese summarized:

> It is my belief that benefit-cost analysis cannot answer the most important policy questions associated with the desirability of developing a large-scale, fission-based economy. To expect it to do so is to ask it to bear a burden it cannot sustain. This is so because these questions are of a deep ethical character. Benefit-cost analyses certainly cannot solve such questions and may well obscure them.

This is why we say the nuclear issues should not be viewed as technical or economic but as an ethical or moral issue.

In fairness, I should point out that nuclear is not the only energy technology shrouded by important ethical issues. Burning up most of the world's supply of liquid and gaseous fossil fuel in one century, a moment in the history of man, is another example. And man may consume most of the solid fossil fuels in a few moments of his hisotry. The risk of serious climatic effects from burning coal is another example.

In conclusion, it makes little sense to focus the nuclear debate on whether the next unit of capacity should be coal fired or nuclear. The key issue is whether you need the next unit of capacity at all. In the short run the only good alternative is energy conservation.

In the longer run the key issue is how we structure our energy policy, including our energy R&D policy. As Amory Lovins has noted, there are two principal policy paths for the rich countries and we must very quickly choose one or the other. The first is energy-intensive, centralized and electric. The second is lower-energy, decentralized and less electrified. The second is based on the efficient