April 5, 1978

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SECY-78-193

INFORMATION REPORT

For: The Commissioners

From: Clifford V. Smith, Jr., Director
Office of Nuclear Material Safety and Safeguards

Thru: Executive Director for Operations

Subject: REPORT ON GOALS FOR RADIOACTIVE WASTE MANAGEMENT

Purpose: To inform the Commission of the publication of two documents prepared by a special task group established to propose goals for radioactive waste management.

Discussion: The staff is publishing for comment a report to the NRC entitled "Proposed Goals for Radioactive Waste Management," NUREG-0300. A copy of the report plus the Federal Register notice announcing the availability of the report and requesting comments are attached as Enclosures 1 and 2 respectively.

The subject report is the product of a seven member interdisciplinary task group of consultants and NRC Staff established in January 1976 to propose goals for the NRC waste management regulatory program. The report is based on findings, interpretations, and analysis by the authors who examined selected literature and interviewed many individuals concerned with waste management.

The authors intended that the scope of their inquiry and proposed goals cover "all technical and societal aspects necessary to an operating waste management system, rather than dealing with the regulatory process alone." Within this scope, "the waste management goals as developed are simple statements of principles which appear to the authors to be important conditions to insure the proper establishment and operation of a system to manage radioactive wastes."

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The goals proposed in the attached report are not directly applicable as operating rules or regulations. Rather they might serve as a checklist of principles which can be used in four ways:

1. As a basis from which to derive licensing criteria;

2. As a standard for evaluating the direction or performance of the waste management system;

3. As a way to focus discussion on the important waste management issues, and

4. As a way to explain the waste management program to the public.

The staff intends to review the report along with comments on the report and to advise the Commission on a policy derived from the goals. In addition, it is the staff's intention to use the report and the analysis of the report and comments by incorporating the relevant goals and discussions thereof into the bases for proposed waste management regulations issued for public comment.

The authors of the report also transmitted essays on issues relevant to radioactive waste management authored by some of the task group members. One of these has been transmitted to the Commission in draft (SECY-76-238, Appendix A); the others are new. The essays add insight into the nature of the waste management problem and the staff is publishing that group of essays as a document entitled "Essays on Issues Relevant to the Regulation of Radioactive Waste Management," NUREG-0412. A copy of this document is attached as Enclosure 3. All of the essays contain portions which are controversial. Further, they do not represent uniform staff or Commission views. We are not requesting comments on this second document. We have not noticed its availability in the Federal Register as it is referenced in the document on proposed goals (NUREG-0300).

Coordination: The Office of the Executive Legal Director has no legal objections to the proposed Federal Register notice of availability of the goals document.

Sheldon Meyer

for Clifford V. Smith, Jr., Director
Office of Nuclear Material Safety
and Safeguards

Enclosures:
1. NUREG-0300 report.
2. Federal Register notice.
3. NUREG-0412 report.

ENCLOSURE 1

NUREG-0300 Report

NUREG-0300

<u>Proposed Goals for Radioactive Waste Management</u>

(A Report to the U. S. Nuclear Regulatory Commission)

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Enclosure 1

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PREFACE

Background

When the Energy Reorganization Act of 1974 abolished the Atomic Energy Commission and established the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC), most waste management activities were transferred to ERDA. There had been no requirements or plans for the AEC to license and regulate the permanent disposal facility which the AEC was ultimately to build and operate. The 1974 legislation, however, required NRC to license and regulate any such facility constructed by ERDA or others.

While the licensing of high-level waste handling and disposal facilities is not the NRC's only responsibility for waste management, it is the focus of much of the public debate over waste management and appears to be the task which arouses the most significant concerns.

Importance of the Waste Management Issue

The debate over the acceptability of nuclear power has intensified because of increasing concern about adequate energy resources on one hand and about potential risks to public health, safety, and the environment on the other. An acceptable waste management program is seen by nuclear proponents and opponents alike as a necessary, though not by itself a sufficient, condition for pursuing nuclear energy as a national energy option. Thus, the character and goals of the national radioactive waste management program are important because the adequacy and acceptability of this program are central to continued public nuclear-powered electricity generation.

This centrality of waste management questions among nuclear power issues enhances the sense of urgency for establishing an operating waste management system. Development and demonstration of such a system did not receive high priority in years past because industry and government were concentrating on developing power generation and fuel supply technologies. Further delay is now publicly unacceptable but so also is deployment of an ill-considered system.

In this report we propose, for public consideration, certain guiding principles for the development, deployment, and operation of a waste management system. It is hoped that by stating system goals now, they will be available for comprehensive evaluation of the proposals, so that public choice of a waste management system will be better informed.

How This Report Can Be Used

The goals proposed herein are intended for modification and evaluation through broadly based participation of concerned individuals and groups. Once this public input has been provided, we expect that some modified version of the goals will be adopted by the NRC and perhaps by other federal and state agencies as well. We believe that an open decision-making process will help establish public acceptance for the system, and thus will help insure that goals finally adopted will be effectively implemented.

Goals and Agency Roles

For the management of radioactive wastes we appear to need neither a breakthough in nuclear physics nor the development of dramatic new technologies. We do need to apply scientific and engineering knowledge within constraints set by openly determined societal goals.

Because of the nature of the waste management problem and the requirement that an adequate solution demands broad action, the goals cover all technical and societal aspects necessary to an operating waste management system, rather than dealing with the regulatory process alone.

By discussing all aspects of the problem in a report to a single agency, we do not imply that NRC or any other agency should be the sole authority for waste management. Nevertheless, we are firm in our conviction that all facets of the waste management problem must be treated together.

ACKNOWLEDGMENT AND DISCLAIMER

During preparation of this document, particularly while it was being reviewed and revised (April-October 1976), help was received from a number of individuals and groups. This help ranged from suggestions of goals or thoughts to be included, through multiple reviews, to recommendations regarding specific language in the report. Reactions to early drafts ranged from praise to condemnation. However, all of the input and reviews were helpful, and we express our sincere thanks.

A great deal was learned during the reviews about the operation of an open program in a bureaucracy. Two lessons were clear. First, statements of a preliminary nature can be used by special interests for their own purposes as though the statements were final. Second, to the credit of all involved, everyone who showed interest in the document was also prepared to put some effort into the project. Again, for that willingness we give acknowledgement and thanks.

The contributors (Appendix A) take complete responsibility for the contents of this report. We freely accepted or rejected thoughts offered by others, therefore the views expressed here are our own. This report has not been reviewed by the NRC staff for consistency with existing regulations or codes.

We found our final draft somewhat critical of past practices in waste management. We did not all begin with that predisposition. Indeed, although the history of waste management in the U.S. is not all good, we suspect that in the same positions and with the same competing priorities, we might have made the same decisions and taken the same actions.

We find that the underlying goals of past waste management practices were consistent in the main with those we present, but that some of the practices, in retrospect, have not measured up. We find that the nuclear community can learn from its mistakes--that because something may have been done wrong once does not mean it will continue to be done wrong. In short, we disagree both with those who maintain that everything is fine as it is, and with those who maintain that it cannot be done better.

During the course of preparing this report some of the authors wrote essays for the purpose of identifying and proposing guiding principles for the regulation of radioactive waste management. Those essays are published separately in a document entitled "Essays on Issues Relevant to the Regulation of Radioactive Waste Management," NUREG-0412.

1.0 INTRODUCTION

The purpose of this report is to propose goals for the national radioactive waste management program, in the hope that such goals will establish a policy basis for the guidance and coordination of the activities of government, business, and academic organizations whose responsibility it will be to manage radioactive wastes. The report is based on findings, interpretations, and analyses by the authors who examined selected primary literature and interviewed many individuals concerned with waste management.

We began our work on the thesis that public goals derive from public concerns. To set goals, therefore, public concerns were identified, their relevance assessed and a conceptual framework was developed that would facilitate understanding of the dimensions and demands of the radioactive waste management problem.

In this introduction we describe the nature and scope of the study and the approach used to arrive at a set of goals appropriately focused on waste management. Further information on the conduct and guiding principles of the study is given in Section 3.0 below.

Nature of the Report

The goals presented here are intended as guides for arriving at a national decision on what system should be chosen and against what standards it should be judged. While the report is in part the product of past decision-making processes, it is also the beginning of a process of public discussion which will lead to adoption of formalized system policies. Perhaps it can also serve as a basis for policy action until a more formally developed statement of goals is available.

The report is not intended to be a blueprint for designers of waste management technology, nor a detailed guide for regulatory decision-making. On the contrary, it urges immediate action and identifies the range of considerations which must be accounted for in establishing the broad, comprehensive policy foundation needed by society for control of the long-term potential hazards of radioactive wastes.

Most of the ideas expressed in this report are not new; many individuals inside and outside the nuclear agencies have been voicing them for a long time. However, not all of the concerns have been systematically acknowledged before. We have heard many views, have tried to understand them, and have attempted to include all those of relevance to this report. What is new about this document is its attempt to set forth comprehensively these long-standing views and concerns.

Scope

The scope of the study is broad. Instead of analyzing specialized aspects of the problem in depth, we surveyed the range of concerns germane to waste management by repeatedly asking "What is the problem?" and "What should be done?" Although this survey can only touch upon the complexity of some of the issues involved, by its scope the study should provide the perspective needed to establish a firm policy foundation for the U.S. waste management program.

The goals are independent of waste type, existing statutory authority, organization of government or business efforts, or the type of technological system that will eventually be deployed. They are not limited to or by the approach presently used in the U.S. to regulate nuclear power. They apply to all types of waste, to developmental and operational activities, and the regulation of all such activities.

We recognize that waste management cannot be totally divorced from the more general debate regarding nuclear power development. Nevertheless, we have refrained from entering that larger discussion, partly because, regardless of whether the present nuclear industry is enlarged, some form of waste management will still be necessary to handle wastes that already exist. More importantly, however, we wanted the document to be based on firm and noncontroversial ground rather than on arguments of advocacy, so that it would be more widely discussed and considered.

Approach

The types of questions and issues considered in the report are complex, and the project was not designed to undertake formal analysis of each issue. We have been guided, at least implicitly, by a set of principles for viewing the issue of waste management. They included (1) that the burden of proof that goals will be met must rest with the proponents of the technology; (2) that reversibility in the implementation of all aspects of the waste management system is a virtue and that irreversibility of chosen alternatives is a flaw; and (3) that full and effective public participation must be provided at all steps of the decisionmaking and implementing processes.

The contributors possess diverse backgrounds in the social and physical science and come from a wide range of institutions. We represent an interdisciplinary research team to frame preliminary conclusions based on various methodological approaches.

The conclusions are proposed goal statements based largely on an examination of a wide topical range of literature (see App. B) as well as on interviews with many people (see App. C). At the conclusion of the first stages of work, each author contributed to one or more sections of the document. These contributions were integrated and a first full draft prepared.

On April 12-13, 1976, about 30 people met in Denver under the auspices of the Western Interstate Nuclear Board to discuss the first draft. Most of those attending represented state agencies or the nuclear power industry. A number of comments, criticisms, and suggested revisions were suggested. A second meeting was held in Palo Alto on May 13, 1976. Five persons, mostly representing environmental and special interest groups, attended that session. Again changes were suggested. Subsequent drafts were reviewed by many interested persons, who also forwarded comments and suggested changes.

The present document contains our findings and proposed goals, tempered by suggestions made during these informal reviews.

General Conclusions

The broad survey approach produced a virtually inescapable conclusion that previous attempts at solving waste management problems have been focused on technological issues to the exclusion of important public policy considerations. Moreover, even those attempts were generally given lower priority than other phases of the nuclear fuel cycle.

In essence, this report reconceptualizes the waste management problem by expanding the set of factors deemed directly relevant to an adequate, publicly acceptable solution. Regulation of nuclear power according to legal standards has traditionally focused on technical areas related to protecting public health and safety. Performance requirements for a waste management program, however, are very long-term, especially in comparison with the 40-50 year operating lifetimes assumed for other fuel-cycle activities. This time requirement forces reconsideration of the factors that must be taken into account by regulatory authorities in evaluating proposed waste management systems as opposed to reactors or other facilities. For example, as the performance lifetime requirement increases, the stability and character of organizations charged with particular tasks becomes increasingly important. No technological system is self-implementing. Even a perfect technological system is useless unless effectively implemented.

In sum, the set of goals proposed herein is the list of factors considered essential to an adequate definition of the waste management problem and to comprehensive evaluation of proposed systems, facilities, and technologies.

We expect that this report will undergo analysis by the NRC staff, the public, various interest groups, and the Commissioners themselves. While we have attempted to survey the entire range of considerations inherent in radioactive waste management, we would not be surprised if further issues were raised, and if further analysis revealed different interpretations of the considerations we have addressed.

2.0 GOALS FOR WASTE MANAGEMENT

Organization; The Temporal Dimension

Production of energy from nuclear fission will likely be merely another episode in energy generation, similar to any other method of power production. It is also probable that the episode will be shorter than the duration of the hazard of the radioactive wastes produced. Thus, the concerns from which our goals are derived have a temporal dimension important to their development and discussion.

Figure 1 is a conceptualization of the temporal dimension which we found useful. Three time periods are suggested:

Time Frame I - The period of active use of nuclear energy, duringhich wastes are produced.

Time Frame II - The period during which society takes an active role in managing the wastes, even if that role is merely surveillance. We assume that this period will be longer than the first, but it could be the same, or even shorter.

Time Frame III- A period during which, because of social discontinuity or lack of concern, society ceases active management of wastes; during this period the system must continue to operate as designed, to isolate still-hazardous wastes from mankind.

The goals suggested below are organized according to these time frames. Such an organization also tends to group the goals by topic, or element of the waste management system. Goals of the first period tend to emphasize the decision-making process. Those of the second period stress implementation, while those of the third deal with radiological hazard and its interactions with the societal system.

Because of the temporal nature of the waste management system, there is a natural progression wherein additional goals must be met at later times, but all must be anticipated in the design and early implementation of the system. Thus, goals pertaining to later periods relate to earlier periods as well.

A further time period which did not enter into the conceptualization or organization of the goals, but which is an important consideration growing from an often-expressed concern, is

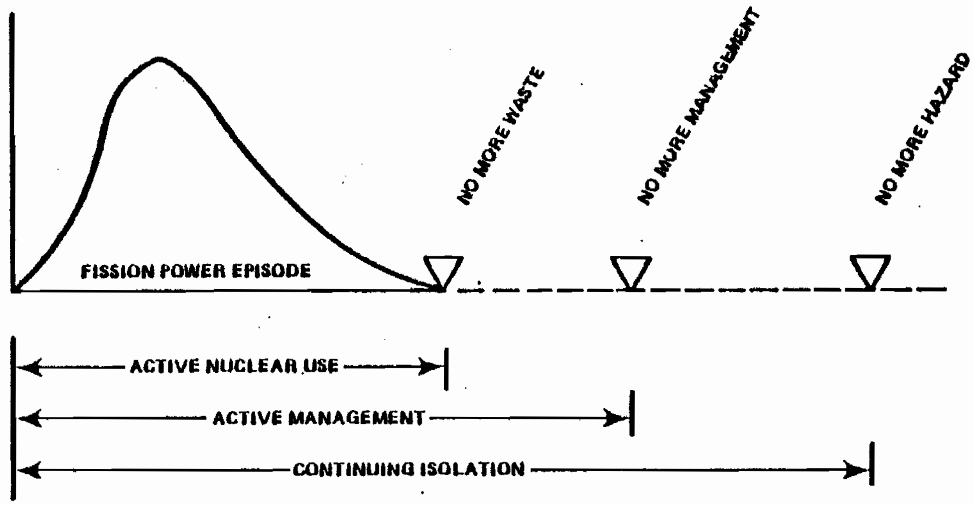

Figure 1 The Temporal Dimension

the immediate future--the next decade or so. Some action must be taken soon to provide management for even the wastes that exist today. It is this time period that is primarily considered both in the programs of federal agencies and in criticisms leveled by critics and the industry.

2.1 Time Frame I -- Goals for the Period of Active Use of Nuclear Power

The time for decision-making and for implementation of the waste management system is during initial stages of the active use of nuclear power. The goal statements that follow emphasize these aspects of the waste management system. Included are goals regarding the decision process, organizations, technology, and radiological protection.

A. THE DECISION-MAKING PROCESS

A.1 THE NECESSITY OF BASING DECISIONS AND ACTIONS ON IMPACT ASSESSMENTS

Decisions and actions shall be based on assessments of all impacts on both present and future human environments.

Comment: An expansion of the considerations involved in the decision-making process has been called for in recent legislation (e.g., NEPA), and is becoming increasingly more important because of pressures of continued growth on limited resources and the limited capability of the environment to absorb the consequent insults.

A.2 THE NECESSITY OF INCLUDING ALL ASPECTS

Consideration shall be given explicitly to all aspects of the waste management system, including safety, environmental, organizational, institutional, and implementational.

Comment: Thinking about waste management has historically been narrowly focused on technological parts of the system, and acceptability has been argued on the basis of the technological issues of practicality and radiation exposure alone. It is now recognized that such systems are not self-implementing -- that organizations are required which meet the same overall requirements as the technology. It is clear that waste management activities have been and continue to be critically dependent on nontechnological factors. Technological aspects of the problem cannot be separated from these societal conditions: all must be treated as integral elements in any effective solution to the management of radioactive wastes.

A.3 CONSIDERATION OF NONQUANTIFIABLE VALUES

Values not easily quantifiable shall be actively considered in the decision-making process.

Comment: While most analyses agree that a wide range of factors must be included in the planning and evaluation of a proposed waste management system, translation of that recognition into an analytical study is difficult. While quantifiable factors such as cancer deaths, environmental pollution, land commitment, and others are of central importance in evaluating waste management systems, they do not exhaust the range of considerations or impacts of the implemented system. Other often nonquantifiable impacts on the societal fabric require understanding and elucidation. Moral and ethical issues can no longer be waved aside simply because they cannot be reduced to an equation. In the decision-making process these nonquantifiable but important considerations must be addressed and given whatever weight their significance demands.

A.4 THE IMPORTANCE OF MAKING UNCERTAINTIES EXPLICIT

The existence of scientific, technological, and organizational uncertainties in any waste management system shall be made explicit, along with the logic and procedures used to address them.

Comment: No one maintains that there is or will ever be complete certainty regarding all aspects of radioactive waste management. A waste management system must be implemented in the face of admitted uncertainties. These will become resolved in the design of the system through some procedure --expert opinion, engineering judgment, limited testing, etc. -- which gives us confidence despite the uncertainty. Both the uncertainties and the means for resolving them should be made clear and explicit. Where there is uncertainty in the knowledge base, the acceptability of and trust in the outcome of decision-making must depend on faith in the procedures themselves.

A.5 MAKING THE SYSTEM ATTAINABLE

The system for managing existing and future wastes shall be within the present capabilities of both technology and organizations.

Comment: The existence of radioactive wastes from weapon production and navy nuclear programs, plus a nearly comparable inventory of fission products in spent fuel (or fuel still in reactors) demands that some best-available technology be employed to manage these wastes. Even the cessation of further production of wastes would not solve this problem. However, the system selected for the much larger inventory of fission products and actinides that will be produced over the next years by the commercial nuclear power industry should not be bound by exigencies that are forcing solutions for the existing wastes (see Goals B.1 and C.2). The impact that would result from selecting an unattainable system for the existing wastes could be severe, and certainly should be part of the impacts considered in the decision-making process.

A.6 INVOLVING SOCIETY IN THE DECISION/PLANNING PROCESS

There shall be broadly based involvement of interested groups, jurisdictions, and citizens in decision and planning processes.

Comment: Because the waste management system involves a number of aspects deserving the attention of a broadly based body, and because radioactive wastes are an important part of the entire nuclear power question, decisions regarding selection and deployment of a waste management system require broad public involvement.

By public participation we do not mean a new populism, nor do we mean decisions made by technical experts in the seclusion of their offices. The decisions needed are a public responsibility, and ways must be found to assure the widest possible public participation.

A.7 INVOLVING STATE, LOCAL, AND REGIONAL GOVERNMENTS

Jurisdictions other than federal (i.e., state, local, and regional) shall be involved in the decision process from the inception of ideas to the implementation of the waste management system.

Comment: State and local jurisdictions have traditionally represented the people on issues of land use, and have continually expressed interest in the location and nature of waste disposal facilities. These jurisdictions must have a role in the decision-making process.

A.8 PUBLIC PARTICIPATION IN THE DECISION PROCESS

The decision-making process shall involve the public at large, including both interested groups and individual citizens.

Comment: It is widely noted that the licensing of a waste disposal facility is a crucial and significant event in the development of nuclear power. Accordingly, there should be wide discourse and participation in decisions regarding radioactive wastes. A number of mechanisms (hearings, rulemaking, etc.) exist or have been proposed for such participation, but none of them have been considered in enough detail to be able to select it to the exclusion of others.

An essential element of public participation is that the full range of information used by the agencies in decision-making be made available. This should include objective information from R&D programs, the full record of agency considerations, and the views of significant actors in the decision process. Such an approach offers hope that the final decision will have been legitimized by the fact that public opinion as expressed through Congress or other means has been a dominant factor.

A.9 ASSIGNING COSTS OF THE SYSTEM

To the extent possible, all costs of a waste management system shall be identified and financial resources assured.

Comment: We adopt as a general principle that all costs of producing nuclear energy shall be borne by those who reap the benefits of nuclear power, including the costs of waste management. This generation should bear the expense of managing the wastes it produces, including capital costs, operating costs, R&D funds, and any compensation due to those disadvantaged by the waste management system (See also D.1).

B. ORGANIZATIONAL CONSIDERATIONS

B.1 PROVIDING ORGANIZATIONAL FLEXIBILITY

Organizations involved in waste management shall have the flexibility to accommodate present and future requirements.

Comment: Operational and regulatory organizations for waste management must provide key technical and managerial skills, and must also possess the ability to modify their actions within overall limitations set by society and by the technology with which they deal. Some aspects of this flexibility are more fully explained in the following goals. Technological aspects are discussed below (see Goal C.2). Organizations involved in waste management should be structured to accomodate the fact that changes in knowledge and in perceptions will alter what is required or is considered optimum at any given time.

B.2 ORGANIZATIONAL RESPONSE TO CHANGES

The organizational infrastructure shall be capable of responding successfully to either gradual or abrupt changes in the rate and scale of activities.

Comment: No matter what realistic projection one uses, the nuclear industry is expected to grow at least during the next half century. The amount of wastes to be managed will increase concomitantly (e.g., the inventory of fission products of concern will about double in the next 3 to 4 years). The organizational infrastructure charged with implementing the waste management technology must be capable of accommodating this anticipated growth, as well as any more rapid growth inspired by improvements in the technology employed. This means, among other things, that plans must be made well in advance and that the organizational system must be designed so that a failure of any of its parts will not vitiate the whole. Similar considerations pertain to any decrease in the use of nuclear power.

B.3 INDEPENDENCE OF THE SYSTEM FROM THE FUEL CYCLE

The waste management system shall be designed so that (1) its operation is independent of the existence of the commercial power system; (2) that other fuel-cycle operations do not restrict flexibility of the waste management system, and (3) that the waste management system does not limit future choices in the fuel cycle.

Comment: A number of decisions regarding the fuel cycle (whether to recycle plutonium, use of the breeder, etc.) are still pending. Further, decisions made today may be altered in the future. A waste management system should neither determine nor constrain these choices, or be limited by them. Because the time during which the waste management system must provide isolation may well exceed the operating life of the nuclear power industry, the waste management system should not rely on the existence of that industry for its own successful operation. Finally, the nature of the system implemented today should not force future decision-making into a choice between alternative fuel cycles.

B.4 ABILITY OF ORGANIZATIONS AND INSTITUTIONS TO DETECT AND RECTIFY ERRORS

Organizational and institutional components of the system shall be designed to ensure detection and rectification of errors.

Comment: This principle is elaborated in the goals pertaining to Time Frame II -- that of active waste management. It is included here because it is important in the design and decision-making phase of waste management. Errors are to be expected, and the organizational design should take their correction into account.

B.5 ASSURING MANAGERIAL COMPETENCE

Organizations implementing waste management systems shall assure competence of operating personnel.

Comment: A number of acknowledged past problems with waste management systems are directly attributable to incompetence or lack of attention on the part of managers. Organizational mechanisms for avoiding such errors are available and should be employed.

B.6 PROTECTING PUBLIC HEALTH AND SAFETY DURING SYSTEM OPERATION

Intermediate operations in waste management (collection, treatment, interim storage, and transportation) shall be performed so as to provide reasonable assurance of protecting public health and safety.

Comment: During this first time period, emphasis regarding public health and safety is toward minimizing the probability of an accident or other untoward event that might give rise to radiological exposure. In general, the mechanism for such protection is waste containment, as distinct from waste isolation, which pertains to the longer term. (Note that similar goals--F.1, G.4--are directed at minimizing long-term consequences.)

B.7 MINIMIZING EFFLUENTS

The fraction of radioactive wastes dispersed into effluent streams for release to the environment shall be minimized.

Comment: To the extent possible, the approach of capture and containment of all waste nuclides should be implemented. While it is impossible to reduce effluents to zero, the dilution of concentrated streams to acceptable effluent concentrations, followed by their release, should not be part of waste management practice; i.e., once concentrated the wastes should be contained, not diluted and released.

B.8 MINIMIZING THE PROBABILITY OF UNTOWARD EVENTS

The system for containing wastes before disposal shall be designed to minimize the probability of radionuclide release.

Comment: The probability that any given level of consequences will occur can and should be reduced. The concept of containment in any given set of accident circumstances is central, but administrative procedures directed at this goal can also reduce probabilities.

B.9 REACTING TO UNTOWARD EVENTS

Procedures shall be established to deal effectively with unintended incidents leading to radionuclide release.

Comment: Both the limits on consequences that should initiate protective reaction and the means of accomplishing that reaction should be built into the waste management system.

B.10 MINIMIZING THE INTERVAL BETWEEN WASTE CREATION AND DISPOSAL

The time from generation of radioactive wastes to the time of ultimate disposition shall be minimized.

Comment: By a shortening of the time during which wastes are under active management, both the amount of dangerous material easily at hand and the likelihood of an untoward event are reduced. The commitment which flows from this goal is timely disposal of wastes. (There may be sound reasons, however, for delaying high-level waste operations for a few years to allow for decay of shorter-lived nuclides.)

C. TECHNOLOGICAL CONSIDERATIONS

C.1 IMMEDIATE ESTABLISHMENT OF A COMPLETE WASTE MANAGEMENT PROGRAM

A complete program for managing radioactive wastes shall be established concurrently with waste generation.

Comment: The responsibility for establishing a waste management program shall not be deferred to future generations or unknown technologies. An easy approach to scientific and engineering problems is to believe that 10 years of careful study at some nominal cost will provide solid answers. Another easy assumption is that a technological innovation is just around the corner. But there can be no certainty about either of these assumptions. We, the present-day generators of wastes, must accept the responsibility for and the consequences of our actions.

C.2 EFFECTS OF PRESENT NEEDS ON FUTURE SYSTEMS

The need to handle, treat, and dispose of radioactive wastes already in existence shall not dictate the nature of solutions for wastes yet to be generated.

Comment: Many wastes produced in both civilian and military programs have yet to be disposed of permanently. Because they exist, we cannot neglect them. But to fulfill this immediate responsibility, given the particular chemical form and the past management of these wastes, a solution which falls short of meeting other goals proposed in this document may be necessary. It is important that acceptance of a system for immediate disposition of existing wastes not be permitted to dictate acceptance of a less-than-adequate management system for future military or commercial wastes.

2.2 Time Frame II -- Goals for the Period of Active Societal Implementation of the Waste Management System

By the time fission power has been supplanted by other sources of electrical energy, society may no longer be producing radioactive wastes, at least from fission power. However, there may still be a need for society to continue active management of wastes from previously operated nuclear reactors. A number of goals pertaining to that time must be met, both during that period and throughout the previous period. Organizational flexibility, continuing radiological protection, and special considerations regarding institutions and organizations are of predominant importance during this period.

D. PROCEDURAL CONSIDERATIONS

D.1 BUDGETARY CONSIDERATIONS

Budgetary considerations shall not be the sole, or even dominant, constraint with regard to the selection, implementation, or continuing operation of a waste management system.

Comment: Part of the process of implementing a waste management system is the assurance of adequate resouces to carry out requisite actions. While this is part of the set of goals for any time frame, it is included in Time Frame II because neither income nor other immediate benefits will any longer be derived from the production of nuclear power. Thus budgetary allocations must be made in advance so that systems set up for the correction of adverse events and/or continuing maintenance will be available (See also A.9).

E. ORGANIZATIONAL AND INSTITUTIONAL CONSIDERATIONS

E.1 ORGANIZATIONS AND INSTITUTIONS TO DETECT AND RECTIFY ERRORS

Organizational and institutional systems shall be such as to ensure detection and rectification of errors.

Comment: To the extent that neither the technology nor the organizations of the waste management system will be perfect, the system, particularly its organizational elements, should be capable of both detecting and rectifying errors. The following two goals address two aspects of this principle. Examples of ways of detecting errors include redundancy, overlapping jurisdictions, frequent checks, independent overviews, etc. An example of ways to allow for rectification of errors is prior allocation of funds, as in a trust fund. Many measures obviously sacrifice efficiency for the sake of reliability.

E.2 SPECIFYING THE NORMAL STATE OF THE SYSTEM

The normal state of the waste management system shall be specified as precisely as possible to facilitate recognition of an undesired or unexpected event or condition.

Comment: Only if there is a clear and accepted standard of normality is it possible to know when a system deviates from normal. Two factors often reduce our ability to specify the normal state of any system, and these should be guarded against. The first is lack of knowledge about the cause/effect relations that influence system operation. We should be able to reduce, if not eliminate, this imprecision. The second factor is the desire by some to retain some ambiguity in order to promote acceptance of the system. Because such ambiguity compromises the ability to detect errors, we should avoid it in describing the normal state of the system.

E.3 DOCUMENTATION FOR THE FUTURE

Adequate documentation of present activities and decisions shall be provided as part of the waste management system, to provide future generations with a basis for action.

Comment: While we cannot assure that future generations will use the information, or even that it will still be available or intelligible to them, we should transmit an information base adequate for future determination of reasonable actions. We cannot dictate those actions, but we can limit them by our own actions.

E.4 IMPLEMENTING ORGANIZATIONS MUST NOT BE SELF-PERPETUATING

Organizational elements of the waste management system shall not be self-perpetuating, nor shall they permit waste management activities to become ends in themselves, independent of the needs of society.

Comment: Waste management systems are designed to protect society from the dangers of radioactive materials, and to do so in ways that will not unduly affect other factors held valuable by society at large. When either of these functions is no longer desired or carried out, the organizational system is no longer needed. In short, the management of radioactive wastes is not an end in itself. We should protect against runaway organizations (e.g., "priesthoods") which inhere in some possible approaches to the waste management problem; and we should be cognizant that large technologies can develop into societal forces in their own right, independent of the needs of the larger society.

E.5 INDEPENDENCE FROM THE POLITICAL SYSTEM

Organizational elements of the waste management system shall not be affected by or require changes in the political system.

Comment: While it is impossible to make any societal activity completely or even largely independent of the political system of which it is a part, there are some aspects in which independence is desirable and can likely be achieved. The essence of this goal is to assure that the waste management system does not depend on alterations of substantive rights of the public (e.g., civil liberties) for its successful operation. Conversely, the goal would assure that a change in the political structure would not adversely affect performance of the system with regard to the protection of health and safety. An adequate waste management program should not require specific attributes in the political system (including changes), nor should it depend on there being no change in that system.

E.6 INTERNATIONAL CONSIDERATIONS

The national waste management system shall take account of and include international considerations to the extent possible.

Comment: Political boundaries have seldom persisted for the lengths of time presently seen as important in waste management. Populations, societies, and institutions are increasingly mobile beyond national boundaries, and certainly released radionuclides from mismanagement of radioactive wastes may be of global concern. Also, in some fuel-cycle options in which plutonium is not recycled, there are implications in the waste management system regarding nonproliferation of nuclear weapons.

For these reasons, and because nuclear power development is already international in scope, it is important that any national program take into account supranational problems, and take an active role in developing internationally acceptable waste management solutions and systems.

F. TECHNOLOGICAL CONSIDERATIONS

F.1 INTERMEDIATE HANDLING AND STORAGE NOT LIMITING

Intermediate handling and storage of radioactive wastes shall be performed in a manner that does not prevent further actions leading to their ultimate disposal.

Comment: Steps and procedures originally seen as interim, temporary, or merely initial, should not become final solutions. Hence, no method of managing the wastes should be left half-done.

F.2 RETRIEVABILITY OF WASTES AFTER DISPOSAL

If wastes are disposed of on earth, their retrievability--assuming a technology as advanced as at present--should not be precluded.

Comment: Because it is partly inconsistent with other goals regarding completeness and permanence of waste management and disposal systems, this goal is offered with some caveats. First, retrievability should be a characteristic of a disposal system only if there is considerable uncertainty about its wisdom, safety, and efficacy. To the extent that uncertainties are small, disposal should be permanent and irretrievable. Second, because long-term stability of social systems cannot be assured, the disposal system should be completed to the point of minimizing requirements on the social systems. Ease of retrievability as used here means that it could be accomplished only at high cost and could be achieved only by societies with technologies at least as sophisticated as our own.

There are enough doubts about this goal that we suggest it be discussed much more fully at each step in waste-disposal planning before it is made policy. The goal would not of course pertain to techniques such as transmutation of isotopes or disposal into space.

2.3 Time Frame III -- Goals for the Period When, Regardless of Societal Involvement, the System Must Continue to Operate

It is reasonable to anticipate that at some time in the future, society will cease to take an active role in maintaining a radioactive waste management system. To the extent that there may be residual danger from the wastes at that time, it is incumbent upon us to design a system that will continue to operate even after the cessation of active societal involvement. The following goals pertain particularly to that time period, but they should be met throughout all other periods during which a hazard persists.

G. TECHNOLOGICAL AND SOCIAL CONSIDERATIONS

G.1 LOCATION AND OPERATION OF DISPOSAL FACILITIES

Waste disposal facilities shall be sited and operated to avoid as much as possible the foreclosure of future options.

Comment: Generalizing from history, we conclude that mankind will seek anything of value, including land and mineral resources--two items of value that might be limited by waste disposal facilities. Further, mankind is now one of the major driving forces for geological change (i.e, erosion, solid movement and water movement). Therefore, to the extent predictable, we should design and locate disposal facilities so as to avoid motivation for penetrating the disposal volume.

G.2 DECOMMISSIONING OF FACILITIES

Nuclear facilities that cannot be decontaminated to normal standards or dismantled and removed shall be considered waste disposal sites, and judged according to the other goals herein.

Comment: At the end of their useful lives, contaminated facilities become radioactive wastes. In the long term only two alternatives are available: radioactive material must be removed from such sites either by decontamination or dismantling, or the locations become de facto disposal sites. In the latter case, there is a risk of disposal site proliferation, which may be undesirable. In any case, each such site should meet the same goals and standards as apply to any other form of radioactive waste.

This goal implies that careful planning must go into original site selection and/or facility design, i.e, decommissioning considerations should be a part of the design of the facilities.

G.3 STABILITIY OF SOCIAL AND GOVERNMENTAL INSTITUTIONS

The waste management system shall not require long-term stability of social and governmental institutions for its secure and continued operation.

Comment: From a historical perspective, such reliance would seem unwise for periods of more than a few centuries, and perhaps incautious for even lesser periods. This goal implies that disposal must be permanent; i.e., that the disposal portion of the system must require no further action by society for the wastes to remain isolated from the human environment.

G.4 COMPLIANCE WITH RADIATION STANDARDS

The waste management system shall be capable of meeting all relevant radiation standards and criteria for both normal and accident situations, throughout its operation.

Comment: If there is a key goal herein, this is it. The crucial characterisitic of radioactive wastes is that they are radioactive. Therefore, for all of the time during which there will be concern about radioactivity, the waste management system should operate in compliance with relevant radiation standards.

3.0 DERIVATION OF GOALS

This report did not begin in a vacuum. We had numerous sources available, as well as a number of starting points.

Assumptions

In addition to the assumptions used to establish the scope, approach, and methodology for this report, the following definitions and assumptions apply to the goals and the conceptual framework on which they were built:

- "Public", as used herein, means the general citizenry and its elected representatives, and also includes local and state agencies, individuals with special concerns or relevant expertise, and special interest groups.
- It is virtually impossible to do anything that has zero risk and at the same time near-zero cost. Therefore, goals must reflect acceptability thresholds greater than zero-risk, while taking into account the benefits anticipated from costs incurred.
- Prudence requires treatment of similar radionuclides by similar methods, regardless of concentration. (Large amounts of diluted waste products may be as hazardous as smaller amounts of more concentrated material if subjected to natural concentrating processes.)
- Goals are not premised on adoption of a particular technical option.
- Goals apply to all forms of radioactive wastes.

Guiding Principles

This effort has been guided, at least implicitly, by a set of principles for viewing the issue of waste management. They included (1) that the burden of proof that goals will be met must rest with the proponents of the technology; (2) that reversibility in the implementation of all aspects of the waste management system is a virtue and that irreversibility is a flaw*; and (3) that full and effective public participation must be provided at all stages of the decisionmaking and implementing processes.

The principles are well articulated in a National Academy of Sciences report entitled Technology: Processes of Assessment and Choice**. The NAS writers note that all too often it is society that has had to bear the burden of proof by being confronted with unanticipated adverse secondary effects:

*The use by this Task Group of the concept of reversibility is limited to the selection and implementation of waste management options; these should indeed allow future alteration or "maneuvering." However, we do not necessarily believe that reversibility of the disposal technique is a virtue. Such reversibility imposed as a design requirement might lead to a lesser degree of waste isolation or a reliance on organizations or institutions for protection against effects of radioactive materials. In the choice of an actual disposal technique, these considerations must be traded against one another.

**See Bibliography

"Society simply cannot afford to assume that the harmful consequences of prevalent technological trends will be negligible or will prove readily correctable when they appear; waiting until deleterious effects become evident entails too high a risk that vested interests--among both producers and consumers--will by then have become so entrenched as to make it politically very difficult or economically very costly to suppress or modify an offending technology or to develop alternative ones." (pp. 34-35)

To remedy that situation the NAS report suggests that the burden of proof be shifted so that the advocates of a technological innovation bear more of the responsibility for establishing the benevolence of their proposal.

Our interviews produced a number of strong and controversial statements in this regard. Some of these charged, in essence, that it is the responsibility of nuclear proponents to produce sufficient evidence to assure society that risks from nuclear power are acceptable for society to bear. While the standards and processes by which society "decides" the acceptability of risks are quite ambiguous and variable, we find here an important concept: that at least initially the burden of proof for the acceptability of a technology should be on its proponents. We believe that placing the burden of proof on the proponents of nuclear power during these initial stages of development will facilitate public awareness, discussion, and decision-making regarding waste management.

As society progresses through the decision-making and implementation processes by which we move technology from drawing boards to operation, the burden of responsibility shifts. In the case of nuclear power technology, the burden first rests with the proponents of a facility. It then shifts to governmental regulators who must certify that the facility meets statutory standards to qualify for construction or operating licenses. Once the technology of a facility is approved, the burden of proof falls upon those who would alter the direction of the decision. In short, the burden of proof of proposing societal action rests with those, whether technologists, regulators, or critics, who would institute the change. In this context, the burden of proof lies today with the NRC to assure that its safety assessments and the licenses it grants thereby are soundly based. The burden of supplying sufficient information for those actions lies with the license applicant (i.e., the actual proponent).

The NAS study also deals with the issue of reversibility. Because it is impossible to assess accurately the costs and benefits of any proposed technological innovation and because future alternatives, needs, and values cannot be known, the writers of the report feel that a fundamental decision premise should be the preservation of options:

"Other things being equal, those technological projects or developments should be favored that leave maximum room for maneuver in the future. The reversibility of an action should thus be counted as a major benefit; its irreversibility, a major cost." (p. 32)

Finally, the NAS writers emphasize the importance of full and effective public participation in decision-making. They observe that proposals for technological changes often have not had close public scrutiny. As a result, diffuse and poorly articulated interests are rarely represented in current decision-making processes. Often what is needed is not conflict <u>resolution</u> but conflict <u>inspiration</u>. The NAS writers call for the creation of "constituencies" to make sure that under-represented interests are given full voice in the decision-making process:

"If one could have some assurance that all the potential losers as well as all the potential beneficiaries were adequately represented.....there would be less reason to fear that decisions would be made on a plainly too-limited basis. Indeed, the very essence of the panel's concern about the narrowness of the criteria that currently dominate technological choices is a conviction that <u>the present system fails to give all affected interests effective representation in the crucial processes of decision.</u>" (p. 41) [emphasis in original]

Sources of Goals

One premise which we felt was fundamental is that goals must be based upon the concerns of society. In other words, our goals did not flow exclusively from the viewpoints of critics or of the industry. However, both of these sources, as well as those who have devised and are devising programs for waste management, provided valuable insights and articulations of guiding principles for the waste management system.

A major source of the goals was the existing body of laws or agency regulations. The large majority of the goals were found in implicit assumptions underlying programs of federal agencies. Most of these same goals, and in large measure the same aspects, were also found in criticisms of ongoing or planned programs leveled by nuclear critics or by special interest groups from the industry. A few of the goals were derived from original thoughts of the authors or from what seemed conventional wisdom about the historical activities of mankind.

Most of these sources were brought to our attention by those we interviewed, by the literature surveyed, or by commenters on early drafts. What we may rightfully claim is the collection and articulation of these concepts. One possible failing of past managers of radioactive waste was the neglect of just such articulation of the reasons for their actions; at least, such statements, if made, had insufficient public visibility.

In Table I we display the major sources of the concepts presented in the goal statements. Because the statements often come from several sources, are frequently stated in entirely different language, or are implicit rather than explicit, we have not attempted to document the sources.

The history of waste management in this country has not been all good. Competing priorities have sometimes caused waste management decisions to be left to future managers and have led to some release of waste nuclides to the environment (though no serious dose to the population has yet resulted). The goals of earlier waste managers may have been the same as ours, and the technology performed generally as anticipated, but implementation of the goals has been lacking in some cases.

Pervasive Themes

Several pervasive themes occur in all sources of the goal statements. Three are worthy of special mention here. First, the notion is widespread that danger from the wastes is manifest in health effects on human beings. Secondly, the time for action is now; few if any feel that the implementation of a full waste management system should be delayed any longer. Third, because of the public mistrust of governmental organizations today, there is a clear demand for consideration of organizations specially designed for effective implementation of a waste management system.

Technological and Nontechnological Factors

Technology is but one of the considerations inherent in the development, deployment, and assessment of a waste management system. Our considerations ranged from the technology to be employed, through the organizations and institutions which will employ it, to the procedures by which the technology and the organizations will both be brought into being. Figure 2 illustrates the overall system that was considered in developing the goal statements. The goals occupy a unique position in the system of interest in that they represent a snapshot at a given moment of a pattern of conditions and concerns that is continually changing. In short, the system

TABLE I: PRIMARY SOURCES OF GOALS

GOAL # - TITLE	LAW OR REGULATION	FEDERAL PROGRAM ASSUMPTIONS	CONCERNS OF PUBLIC/CRITICS/ INDUSTRY	CONVENTION WISDOM*
A.1. The Necessity of Basing Decisions and Actions on Impact Assessments	X	X	X	
A.2 The Necessity of Including All Aspects	X	X	X	
A.3 Consideration of Nonquantifiable Values			(X)	X
A.4 The Importance of Making Uncertainties Explicit	(X)		X	
A.5 Making the System Attainable		(X)	X	
A.6 Involving Society in the Decision Planning Process	X	X	X	
A.7 Involving State, Local and Regional Governments		X	X	(X)
A.8 Public Participation in the Decision Process	X	X	X	
A.9 Assigning Costs of the System		(X)	(X)	X
B.1 Providing Organizational Flexibility				X
B.2 Organizational Response to Changes		(X)	(X)	X
B.3 Independence of the System from the Fuel Cycle		(X)	X	X
B.4. Ability of Organizations and Institutions to Detect and Rectify Errors			X	X
B.5 Assuring Managerial Competence	(X)	(X)	X	

TABLE I: PRIMARY SOURCES OF GOALS CONTINUED

GOAL # - TITLE	LAW OR REGULATION	FEDERAL PROGRAM ASSUMPTIONS	CONCERNS OF PUBLIC/CRITICS/ INDUSTRY	CONVENTION WISDOM*
B.6 Protecting Public Health and Safety During System Operation	X	X	X	X
B.7 Minimizing Effluents	X	X	X	
B.8 Minimizing the Probability of Untoward Events		X	X	
B.9 Reacting to Untoward Events	(X)	X	X	
B.10 Minimizing the Interval Between Waste Creation and Disposal	X	X	(X)	
C.1 Immediate Establishment of Complete Waste Management Program		X	X	
C.2 Effects of Present Needs on Future Systems	(X)	X		X
D.1 Budgetary Considerations			(X)	X
E.1 Organizations and Institutions to Detect and Rectify Errors		(X)	(X)	X
E.2 Specifying the Normal State of the System				X

TABLE I: PRIMARY SOURCES OF GOALS CONTINUED

GOAL # - TITLE	LAW OR REGULATION	FEDERAL PROGRAM ASSUMPTIONS	CONCERNS OF PUBLIC/CRITICS/ INDUSTRY	CONVENTION WISDOM*
E.3 Documentation for the Future			(X)	X
E.4 Implementing Organizations Must Not Be Self-Perpetuating		(X)		X
E.5 Independence From the Political System			X	X
E.6 International Considerations		X	X	
F.1 Intermediate Handling and Storage Not Limiting	(X)	(X)	X	
F.2 Retrievability of Wastes After Disposal			X	
G.1 Location and Operation of Disposal Facilities		(X)	X	(X)
G.2 Decommissioning of Facilities			X	X
G.3 Stability of Social and Governmental Institutions		(X)	X	X
G.4 Compliance with Radiation Standards	X	X	X	X

X = Primary Source
(X) = By implication
* Ideas which the Task Group found compelling but which had no identifiable source in the usual radioactive waste management discussions.

components are: technology, organizations, institutions (e.g., laws and mores), society at large, the decisions made by either society or organizations charged with that role, the processes by which the decisions are made, and implementation of the decisions. The process is iterative, as shown in the figure.

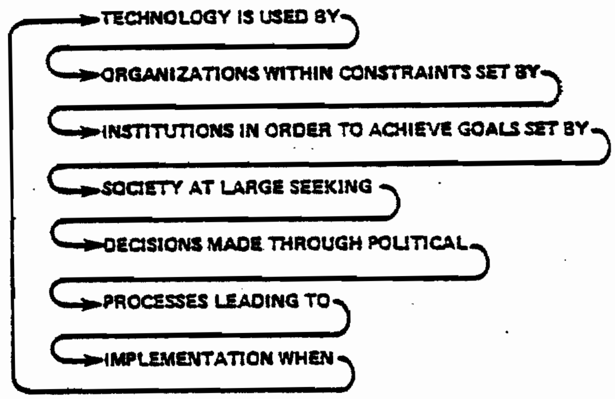

Figure 2 The System

We were struck by the close interrelationships between the technological and nontechnological components required by any waste management system. We believe that dealing with the two together for the purposes of implementation will avoid significant distortions and will increase the likelihood that the system will operate as desired.

The intimate connection between the technological and the nontechnological stems from two considerations. First, no technological system is self-implementing; all depend on organizations and institutions for their operation. Second, highly complex technological systems invariably have secondary consequences beyond the bounds of the technological system itself. These indirect effects alter the character of many aspects of the social system.

At the least, there will have to be organizations to oversee the treatment, transportation, and disposal of radioactive wastes produced in commercial reactors and fuel-cycle facilities. Such an organizational infrastructure must be capable of responding to changes in scale of operation as the nuclear industry matures. Perhaps more importantly, it must be able to continue to perform as its operations lose their initial sense of excitement and become routinized. For example, we can imagine that over time many of the best people in the organization might leave. Remaining personnel may become less motivated, less concerned about operating and maintaining the facility at its optimum.

Our main point is that waste management programs, like all human activites, involve both technical hardware and human organizations. Shortcomings in either will affect how well a program is implemented. This suggests that as much attention should be paid to management and institutional considerations as to technological ones.

The waste management system introduces special questions of organizational design. For instance, the requirement that any ultimate high-level waste repository be sited on federal lands suggests the possibility of long-term governmental involvement in control of the land, or even in some program of surveillance and monitoring.

Yet mankind has not been skilled in ensuring long-range planning and implementation. The time horizons of the relevant actors are short compared to the time periods involved here. Examples of attempts at long-term planning (e.g., Social Security) encourage caution. These issues need to be considered explicitly in the design of any waste management system.

Additionally, the organizational system once in place can fall into patterns of action which may not align with the original objectives. For instance, when specifically threatened, a bureaucracy often reacts to protect its central resource, its constituency, or the role for which it is responsible. The NAS panel noted:

> "It has often been said that administrative bodies, surrounded by the interests they are supposed to evaluate and regulate, tend gradually to lose sight of the large purposes that attended their birth and eventually to make common cause with those interests. .....Any human institution has tendencies that, unless counteracted, will over time cause it increasingly to be run for the benefit of people inside the organization or for those special outsiders with whom they have found it easiest to identify themselves."

We can expect that the radioactive waste managers of 2050 will react to protect their status quo: the waste management system as it then exists and the customers of that system.

In addition to the integral role that organizations play in implementing waste management programs, nontechnological factors must be considered also because they are affected by operation of the waste disposal system. For example, there are likely to be direct socioeconomic impacts such as general effects on the economy, or geographical distribution of population, on communities located near the waste disposal facility, and even on government expenditures and revenues.

There may also be indirect effects. The effects of a waste management system on civil liberties have not been analyzed exhaustively, but a "priesthood" has been suggested as necessary, and guard forces are already required for the protection of sensitive materials and facilities from sabotage. A major accident at the few places in the waste management system where the effects could be great could have profound psychological consequences.

Through these illustrations, we hope we have made clear our conviction that nontechnological factors are inseparable elements of any waste management system.

In the decision-making process by which the waste management system is being selected and implemented, nontechnological elements play a key role. Because the factual basis for decisions is never complete and unequivocal, actions are often based on judgments by experts. The attribution of credibility to experts who provide these judgments is one part of the decision-making process that requires careful attention. Further, where the system under consideration is complex, special methodologies are often brought to bear for purposes of analysis and guidance. The results of these methodologies are not necessarily exhaustive and should not be taken as gospel.

In short, then, the factors or elements to be considered in setting goals for the waste management system range across all the societal elements illustrated in Fig. 2.

These goals and the system requirements derived from them (e.g., regulations) can and do change with time, but certain of the concerns on which the goals are based will remain unchanged.

4.0 TRANSFORMATION OF GOALS INTO POLICY AND REGULATIONS

Normally in the development of policy and its translation into law, regulations, or practice, goals (or objectives) are the first statements to be formulated. In the present instance, however, a number of regulations, practices, and laws already exist which deal specifically with radioactive wastes. Consequently, the goals herein incorporate some that are already implicit or explicit in current programs or in the existing legal framework. The present application of these goals is to provide a conceptual structure within which to judge developing programs and regulations to determine their adequacy in meeting societal needs.

For the NRC, the adoption of goals is merely the first step in an involved process. The conclusion of the process is the emergence of regulations and regulatory guides in which general aims are transformed into specific requirements.

Unlike other aspects of the regulation of nuclear power, the conceptual framework and the data bases for developing regulations on waste management are still deficient. Uncertainties will remain on such fundamental technical issues as geological stability and radionuclide migration. Even greater uncertainties will be associated with nontechnological aspects of waste management. The social science of waste management is quite rudimentary. Organizational theorists will not find it easy to design implementing systems. Political scientists still need to define fully decision-making procedures that will ensure full and effective participation by interested groups. This does not mean that those issues can be ignored or discounted; even limited vision is better than blindness.

Because these inherent uncertainties exist, transformation of the goals into specific regulations will require a dual perspective:

- From a legal perspective, regulations have the force and effect of law and are the means by which the Commission announces what actions must be taken or prohibited in order to protect the health and safety of the public. When promulgated, regulations also become the standards by which the program is administered. From this perspective, regulations perform traditional and customary functions, one of which is to provide a stable or static regulatory environment on which industry and regulated agencies can rely in making decisions with respect to the various programs and actions.
- From a management perspective, because inherent uncertainites permeate almost all subject matters on which the regulation of radioactive wastes are based, NRC ought to treat the regulations themselves as working hypotheses that must be verified by experimental and empirical means. That is, the regulations must be interpreted as assertions that if X is done, result Y (which fulfills a particular goal) will assumedly follow.

The necessity to adopt this dual perspective has several important implications:

- It is not sufficient merely to write a set of regulations or guidelines; methods of testing their validity must be simultaneously established.
- Criteria must be established well in advance for judging when a regulation-hypothesis has been disconfirmed.
- NRC must be willing to revise regulatory hypotheses should they be disconfirmed, and a mechanism for revision should continue to be available (as it now is).
- NRC must have organizational components and management programs (separate from its usual legal and regulatory activities) which are responsible for validating the hypotheses contained in the regulations, for developing new hypotheses, and for transforming both into new regulatory requirements as needed.

It is easy through inertia to maintain a regulation after its utility has faded or it has been disconfirmed. Avoiding such a pitfall places an important responsibility on the NRC, and the agency should continue to be willing to revise any of its hypotheses on the basis of information of substance from any source.

Appendix A

Contributors

The contributors to the report were individuals of diverse backgrounds, training, and present career interests. They were:

Sociology/Systems Analysis	--Ida R. Hoos University of California Berkeley, Calif.
Political Science/Government Decision-making	--Daniel S. Metlay Indiana University Bloomington, Indiana
Law/National Policy	--Ward C. Stoneman Quarry Hill, Inc. Arlington, Va.
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Appendix B

Selected Bibliography

In the following, we have listed some of the printed material that was found useful during the course of this task. The list is not intended to be complete, but rather to reflect the balance of material studied.

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Appendix C

Interviewees

Listed below are the persons with whom we have discussed the radioactive waste management problem during the early days of our deliberations. In this list, we have attempted to be as complete as possible and have included most of those who contributed to our own thinking on the problem.

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ENCLOSURE 2

Federal Register Notice

NUCLEAR REGULATORY COMMISSION
Proposed Goals for Nuclear Waste Management
Task Force Report

Notice is hereby given that a report, "Proposed Goals for Nuclear Waste Management," NUREG-0300, is available for public comment. This document is a report to the NRC Staff from a contractor and staff study and is in response to a request by the Commission for a set of comprehensive goals to be met by the NRC nuclear waste management regulatory program. The views expressed in the report are those of the authors and do not represent the views of the Commission or the staff. The contributors to the report represent diverse disciplines and have submitted to the staff a report which reflects these diverse backgrounds and points of view as brought to bear on nuclear wastes. The authors extended the scope of their inquiry to cover "all technical and societal aspects necessary to an operating waste management system." The report is based on findings, interpretations and analyses by seven individuals who examined selected primary literature and interviewed others concerned with waste management. Most of the ideas expressed in this report are not new; many individuals inside and outside the nuclear agencies have been voicing them for many years. However, not all of the concerns have been systematically acknowledged before.

In brief, the report "identifies the range of considerations which must be accounted for in establishing the broad comprehensive policy foundation needed by society for control of the long-term potential hazards of radioactive wastes." The goals fall into three time periods and are summarized in a Table following this notice. They could form part of a basis from which to derive licensing criteria and regulations for nuclear waste management; they are principles by which one could judge whether a proposed system measures up to the overall goal of protecting things valued by those whom the system serves; and they could serve to focus public debate on important waste management factors. However, no decision has been made regarding these uses by the Commission.

All interested persons who desire to submit written comments on the report and its proposed goals should send them by ____________ to the Assistant Director for Waste Management, Division of Fuel Cycle and Material Safety, Office of Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

Copies of the report may be examined at the Commission's Public Document Room at 1717 H Street, Washington, D.C., and at the Commission's local Public Document Rooms. Copies of the comments received in response to this notice will be placed in the Public Document Room in Washington, as received. Single copies of the report may be obtained without charge, to the extent of supply, by writing to the Division of Document Control, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555. Thereafter copies may be obtained from the National Technical Information Service, Springfield, Virginia 22161, at current rates.

Dated at Washington, D.C. this day of 197 .

FOR THE NUCLEAR REGULATORY COMMISSION

William P. Bishop
Assistant Director for Waste Management
Division of Fuel Cycle and Material Safety
Office of Nuclear Material Safety and Safeguards

SUMMARY OF GOALS

Goals / Time Period	Active Use of Nuclear Power and Production of Wastes	Active Societal Involvement in Management of the Wastes	No longer Active Involvement yet Some Hazard Remains
Procedural and Decisional	. All impacts and aspects should be considered (technology is not self-implementing) . Resolution of uncertainties should be explicit . Attainable within current technology . Broad public involvement should be sought--open decision-making . Assign cost to user	. Cost should not be dominant constraint . Arrangements should be made in advance for required actions	. Future land-use options should be protected . Decommissioned Facility is a *de facto* disposal site if not dismantled--should be treated accordingly
Organizational Goals	. Flexibility to respond to scale changes; organizational flexibility; reversibility of decisions . Independence of waste management from the rest of the fuel cycle . isn't driven by nor drives fuel cycle . organizations designed to detect and rectify errors . assure managerial competence	. Flexibility for error detection and correction . Specify normal state of system . Documentation for future . system should not be self perpetuating . Independence from political system . International considerations	. Should not require stability or continuity
Health and Safety Goals	. assure health and safety of intermediate operations . Minimize probabilities of untoward events, effluents, and reaction times . Minimize time between creation and disposal of waste		. Continue compliance with relevant standards
Technological Considerations	. Action not put off to future--design complete system	. Intermediate solutions not limiting (they shouldn't become final)	. Disposal should be permanent

ENCLOSURE 3

NUREG-0412 Report

NUREG-0412

ESSAYS ON ISSUES RELEVANT TO THE REGULATION OF RADIOACTIVE WASTE MANAGEMENT

Essays by:

William P. Bishop

Norman Hilberry

Ida R. Hoos

Daniel S. Metlay

Richard A. Watson

Enclosure 3

Table of Contents

Preface

This volume contains a collection of essays prepared by the individuals who participated on a Special Task Group for the United States Nuclear Regulatory Commission (NRC) for the purpose of identifying and proposing goals (or guiding principles) for the regulation of radioactive waste management. The report of the Special Task Group to the NRC is contained in "Proposed Goals for Radioactive Waste Management", NUREG-0300.

For the most part, the material for these essays grew out of the information collected during interviews, from literature, and from discussions with concerned parties. In some cases, these essays represent a further refinement of ideas, thoughts, and concerns held by the authors prior to their involvement in the Special Task Group. The positions expressed and the conclusions reached in these essays are the sole responsibility of the authors. This material has not been reviewed by the NRC staff and it does not necessarily reflect or represent NRC policy or positions. These essays are offered in this volume for the purpose of providing a means for the authors to express their views and to make those views available to the public.

HISTORY AND INTERPRETATION OF RADIOACTIVE WASTE MANAGEMENT IN THE UNITED STATES

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HISTORY AND INTERPRETATION OF RADIOACTIVE WASTE MANAGEMENT IN THE UNITED STATES

Preface

This is an interpretive history of radioactive waste management in the United States. It is interpretive because we seek to tease out the significant strands of policy and organizational behavior rather than to give a complete chronicle of past actions. As a result, it does not contain a detailed description of what occurred in every facet and phase of the Atomic Energy Commission's involvement in waste management. Instead, some aspects have been emphasized and others hardly touched.

This allows us to focus on broad themes of behavior and variations on those themes. We highlight those things which stand out as being particularly critical in the history of waste management. From discussions with a number of people, both practitioners and observers, we believe we have captured many, if not all, of the important patterns of how waste management policy was determined and implemented. Nevertheless, interpretive history is often highly error prone. The reader must depend on the analyst's ability to scan sensitively the entire history to select for comment those parts which are, in fact, essential to a fair and complete understanding of the whole.

A Chronicle of Waste Management

Historically, waste management decision-making has been characterized by periods of unconcern interspersed with moments of intense interest. Lacking the sex appeal of reactor development and the pork barrel quality of other segments of the fuel cycle, waste management became, organizationally and operationally, a residual category. Herein we give a brief synopsis of the significant events in the history of waste management, and then this history's significant themes are developed. Examples from the past are used to illustrate them. Some lessons are drawn which need to be understood and headed by those who design future waste management systems.

Origins and Background

The creation of today's unwanted radioactive waste legacy resulted from many small, past actions, premised on limited vision and constrained by few resources, severe time pressures, and overwhelming competing priorities. Nowhere is that description more accurate than in the case of the wastes generated by the Atomic Energy Commission's military program.[1]

The AEC has operated three facilities--at Hanford, Washington; at Savannah River, South Carolina; and at the National Reactor Testing Station in Idaho--for the purpose of producing plutonium in reactors for the weapon's program or to process irradiated fuel from experimental reactors as well as from the reactors of the Nuclear Navy. As of 1974, these wastes, in the form of liquids, salt cakes, sludges, crystals, and calcine granules represented some 85 million gallons.[2] Today, those wastes constitute what many believe to be the waste management problem.

The production of wastes is an inextricable part of the operation of nuclear facilities; as soon as a uranium atom absorbs a neutron--whether it be in a production, research, naval, or civilian nuclear power reactor-wastes are produced and the need to manage them becomes manifest. Different strategies for management were adopted at each of the three AEC facilities. At Hanford, the acidic waste streams have been neutralized and then stored in single-walled carbon steel tanks. The non-boiling wastes are now being solidified in their tanks. The self-boiling wastes are being fractionated to remove the long half-life heat generating isotopes of cesium and strontium. At Savannah River, the neutralized waste solutions are stored in carbon steel tanks that sit like cups in saucer-like carbon steel shells. At Idaho, the wastes, initially stored in stainless steel tanks, are calcined (solidified) and are then put into stainless steel bins which are housed in concrete structures. The solidified wastes can be easily retrieved. Present and future plans for these wastes are summarized in Figure 1.[3]

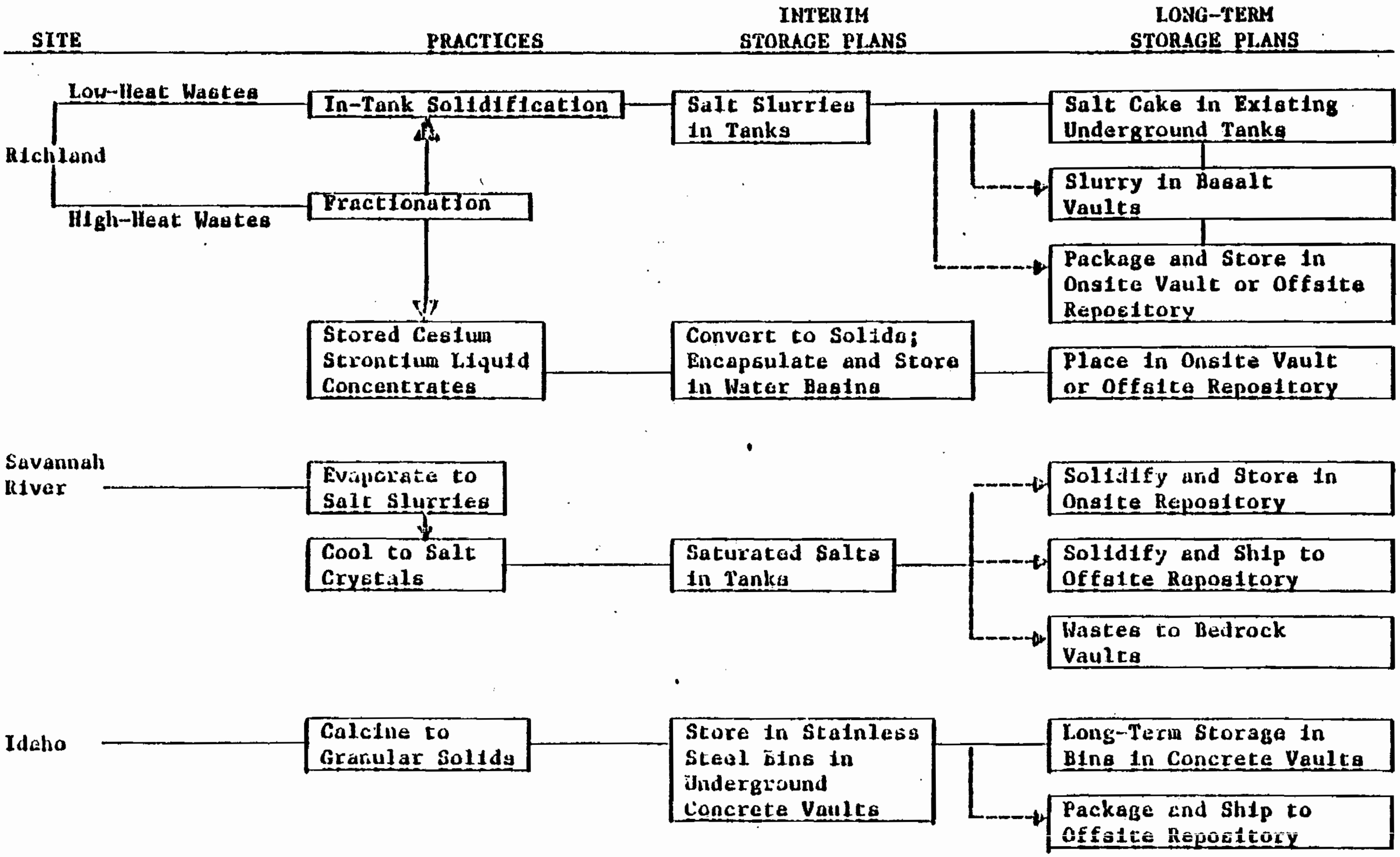
[1]See, for example, the GAO report, Observations Concerning the Management of High Level Radioactive Waste Material, May 28, 1968. (1968 GAO Report)

[2]GAO report, Isolating High-Level Waste From the Environment: Achievements, Problems, and Uncertainties, December 18, 1974, pg. 8. (1974 GAO Report)

[3]Figure is taken from WASH-1202 (73) Plan for the Management of AEC Generated Radioactive Wastes, pg. 42.

FIGURE 1

COMPARISON OF PLANS FOR LONG-TERM STORAGE OF HIGH-LEVEL RADIOACTIVE WASTES



NOTE: Solid lines indicate current plans; dotted lines indicate alternates.

Waste management operating experiences at each of these three facilities have differed as well. The worst record has been at Hanford. Beginning in 1956, a total of 18 separate leaks have been detected in which 450,000 gallons of liquid entered the environment.[4] An unknown number of potential leaks were forestalled by transferring the waste solution from weakened tanks to others of greater strength. The secondary containments used at Savannah River have prevented major releases to the environment; less than 100 gallons of waste have escaped into the soil there.[5] The best record has been compiled at Idaho. There the use of stainless steel tanks has eliminated the need to neutralize the waste stream emerging from the reprocessing plant. This, in turn, has made it possible to calcine the wastes. The now solid waste can be stored and handled easily; the only precaution that must be taken is to isolate the highly leachable solids from water in the environment. To date no accidents have been reported at the Idaho facility.[6]

The basic conceptual framework for civilian waste management, which still dominates most people's thinking emerged from a report by the National Academy of Sciences' Committee on Waste Management in 1957. The Committee noted that "the most promising method of disposal of high level waste at the present time seems to be in salt deposits."[7] Four years later, in another report the same advisory committee remarked that "Experience both in the field and in the laboratory on the disposal of wastes in salt have been very productive and well conceived; plans for the future are very promising."[8]

The imprimatur of the Academy stimulated a research program under the direction of the Oak Ridge National Laboratory (ORNL). A major part of that program, called Operation Salt Vault, was to determine the consequences of exposing bulk salt to radiation and heat. The site of the experiment was an abandoned salt mine near Lyons, Kansas. Spent fuel elements were used to represent solidified waste because the latter was not available at the time. Electric heaters were also used to simulate the thermal output of the waste in some experiments. (Because of the experimental character of Project Salt Vault, retrievability was built into its design from the very beginning.)[9] Efforts were made by the ORNL staff to conduct the effort in full view of the Kansas population. Consultations were held with the local citizenry before the project began. Once the experiments started operating, regular tours were conducted in which the general public could visit the mine. The reversibility of the effort and the openness of its implementation produced a climate of acceptance. If not loved by all, as some participants claim, at least Project Salt Vault did not evoke fears and horrors in the minds of the central Kansas population. However, despite its initial promise and ultimate success in producing data, Project Salt Vault never really enjoyed much support from the Reactor Development Division at the AEC. Funds had to be "bootlegged" by ORNL from other projects simply to keep it going, but if the ORNL salt experiments were initially neglected, events soon conspired to propel them into view.

A fire at the AEC weapons facility located in Rocky Flats, Colorado, gave rise to a large volume of low level, plutonium contaminated debris. Following its standard operating procedures, the Division of Military Application of the AEC forwarded that waste to the Idaho Reactor Testing Station for burial. That action outraged Idaho's Senator Frank Church, who saw no reason why his state should become the dumping grounds for Colorado's waste. Church acted and extracted a commitment from AEC Chairman Glenn Seaborg that all of the waste stored in Idaho would be removed at the end of the 1970's.[10]

At the same time, steps were being taken to formulate and to formalize a regulatory policy concerning commercially generated wastes. Up to that point, whatever policy existed had been more or less ad hoc, a result of a set of individual decisions such as those made in the licensing of the Nuclear Fuel Services reprocessing plant and the five low-level commercially

[4]See ERDA-1538, Waste Management Operations at Hanford Reservation, Vol. I, pg. III.2-2 and Vol. I, pg. II.1-c.

[5]1974 GAO Report, pg. 13.

[6]Ibid, pg. 13.

[7]NAS/NRC Report: The Disposal of Radioactive Waste on Land, Sept. 1957, pg. 4. (1957 NAS Report)

[8]See Radioactive Waste Repository, Lyons, Kansas (EIS), Washington, AEC, 1971, p.9.

[9]See R. L. Bradshaw, W. C. McClain, and J. O. Blomeke, Radioactive Waste Repository in Salt: Preliminary Cost Estimates and Comparison of Alternative Sites, ORNL-CF-69-6-69 (June, 1969); and Bradshaw and McClain, eds., Project Salt Vault: Demonstration of the Disposal of High Activity Solidified Wastes in Underground Salt Mines, ORNL-4555, April 1971.

[10]Interview with Frank Pittman and Alex Perge. See also letter from Seaborg to Sens. Church and Jordan, June 9, 1970.

operated burial grounds. That first systematic attempt to develop a waste management policy led ultimately to the adoption of Appendix F to 10 CFR 50.[11] Among its other provisions, the regulations provided that solidified wastes shall be "transferred to a Federal repository no later than 10 years following the separation of fission products from the irradiated fuel." Thus, the Rocky Flats fire and the now officially acknowledged need for a repository stimulated the Commission to transform the early experimental efforts at the Kansas salt mine into a demonstration repository.[12] If necessity forced the decision, it did not seem premature at the time. In the words of one of the AEC managers, "It was time for ORNL to put up or shut up. Either they should design a facility or stop claiming it was technically possible."

The Commission considered locating the facility in Kansas, Michigan, and New York. None of those three alternative sites possessed any great geological advantage over the others: each appeared quite suitable. Three factors swung the decision in favor of the Lyons, Kansas, site:

1. Detailed information on the area had been gathered as part of Project Salt Vault.

2. There was a sense of confidence in receiving a "favorable reception on the part of local and State officials and private citizens."

3. There was a recognition that "necessary investigations to prove out the acceptability of (the other) sites would result in considerable delay estimated on the order of two years."[13]

That June 12, 1970, decision was followed five days later by an AEC press release that explicitly stated that the selection was tentative. That few people believed that claim was a harbinger of things to come. Among those who reacted negatively were the members of the Kansas Geological Survey who were meeting with the National Academy of Sciences' Radioactive Waste Management Committee that very day in Lawrence, Kansas, to consider the suitability of the Lyons site. The press announcement clearly suggested to the men from Kansas that their views would only marginally affect the decisionmaking process. This, in turn, led to the formation of long lived and highly damaging resentments. It was hardly an auspicious beginning.

It was all down hill from there. Relations between the AEC Reactor Development Division under Milton Shaw and ORNL were never pleasant; the Lyons' project certainly did nothing to improve them. The managers at AEC headquarters complained that the ORNL directors never fully appreciated the the fact that they were constructing an operational facility, not designing a research center. Increasingly, the AEC Reactor Development Division personnel felt that calculations that had been presented as complete and sophisticated were actually "back of the envelope" efforts. Belief that sloppy technical work was being combined with disregard for the pragmatic realities of the project quickly soured the Reactor Development Division managers on ORNL.

Nor was the ill will one-sided. For their part, scientists from ORNL accused the AEC headquarters bureaucrats of behavior which could be termed technologial arrogance. The ORNL scientists observed the fund of good will that they had built up among the local population over many years being dissipated. In their view, the outsiders from Washington treated the local scientists at the State Geological Survey and at the State University in such a patronizing and condescending manner that it bordered on contempt. Perhaps as important, at least subconciously, the ORNL scientists saw themselves being ignored and pushed into the background when it came to policy decision-making.

However, the tension which existed between ORNL and AEC headquarters was insignificant compared to the fundamental cleavages that developed between the Kansas scientists and the AEC. The leader of the technological opposition was William Hambleton, the Director of the Kansas Geological Survey and a member of the National Academy of Sciences panel convened to assess the Lyons' project. Hambleton's ire at the AEC was first aroused in two initial meetings held between the AEC and the Academy panel in the spring of 1970. At that time, he felt that the AEC personnel were insensitive in their dealings with the Academy in general and with him in particular.

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[11] See AEC 180/88 Siting of Commercial Fuel Reprocessing Plants and Related Waste Management Facilities, June 17, 1970.

[12] See AEC 180/87 Solid Radioactive Wastes: Long Term Storage in Central Kansas Salt Mine, June 12, 1970.

[13] AEC 180/87, pg. 4, 16.

Hambleton's objections were not entirely caused by personal pique. He was convinced that the ORNL calculations were too primitive to allow any statement about the safety of the repository to be made. Hambleton was concerned that not enough was known about possible radiation damage to the salt, about waste canister movement in the salt, and about retrievability. Most importantly he was skeptical about the calculations on heat transfer extrapolated from a two dimensional to a three dimensional model.[14]

Those scientific objections provided a basis for political opposition. The political forces were led by Kansas Representative Joseph Skubitz and by Governor Robert Docking. Together they attacked peripheral issues in the hope that the project would collapse. The forecast of the AEC staff for ready public acceptance of the Lyons' project proved to be extraordinarily optimistic. While the Kansas opposition never succeeded in stopping the project, it scored something of a triumph when the Congress passed an Amendment to the 1972 AEC Authorization Bill. The amendment sponsored by Kansas Senators Pierson and Dole, but instigated by Skubitz, prevented the AEC from implementing the Waste Repository Project until a distinguished advisory commission certified that the project was safe.[15]

The AEC personnel, however, viewed these attempts at political harassment almost disdainfully. They proceeded confident that despite some unresolved problems a technical solution could be found. None of their studies turned up any information that altered that view. To be sure, there were more bore holes from gas and oil exploration than had been expected, but given time and resources those could be successfully plugged. ORNL proceeded down the road to implementation carrying out confirmatory tests that would fulfill the conditions that the NAS had imposed in their report tentatively affirming the suitability of the Lyons' site.

Then in September, 1971, the AEC Reactor Development Division was informed that the American Salt Mining Company had undertaken a massive effort using hydraulic fracturing in a mine two to three miles south of the proposed repository. (See Figure 2) It was initially thought that the outcome of that action would be to remove virtually all the salt in that area. If that were the case, subsidance followed by the formation of "Lake Lyons" was a definite possibility. Such a lake would threaten the integrity of another American mine which in turn was located a mere 1,700 feet from an extension of the Carrie mine which again in turn was part of the repository itself. This potentiality was the straw that broke the Lyons' project. The Reactor Development Division Manager of the program returned to Washington convinced that the AEC was "now in a no win situation." No technological fix could ever be developed that would convince the public that the danger was minimal.

This turn of events was soon followed by a warning from the Nixon White House to the AEC: do nothing to rock the boat this close to the election. The new AEC Chairman, James Schlesinger, and a new AEC Commissioner, William O. Doub, were especially sensitive to this plea. Slowly, Lyons faded into the background. By February, 1972, the repository project in Kansas was officially dead.[16]

The AEC had been burned by the waste issue. Schlesinger reacted by refusing to consider any plan which involved burials at depths less than 10 miles and by pressing for consideration of exotic waste management alternatives such as transmutation and space disposal.[17] However, some new practical concept had to be developed in the short run. The AEC could not afford to be seen as having no waste management policy. Under the direction of the new Director of the Division of Waste Management and Transportation, Frank Pittman, the notion of an engineered Retrievable Surface Storage Facility (RSSF) was developed. Mausolea would be constructed in the West for the storage of AEC and commercially generated waste. Once a permanent repository was developed the waste could be transported to it.[18] This policy, announced in May, 1972, survived one challenge 18 months later. The General Manager proposed that instead of building an RSSF, the solidified waste be stored at the reprocessing plant until a permanent repository

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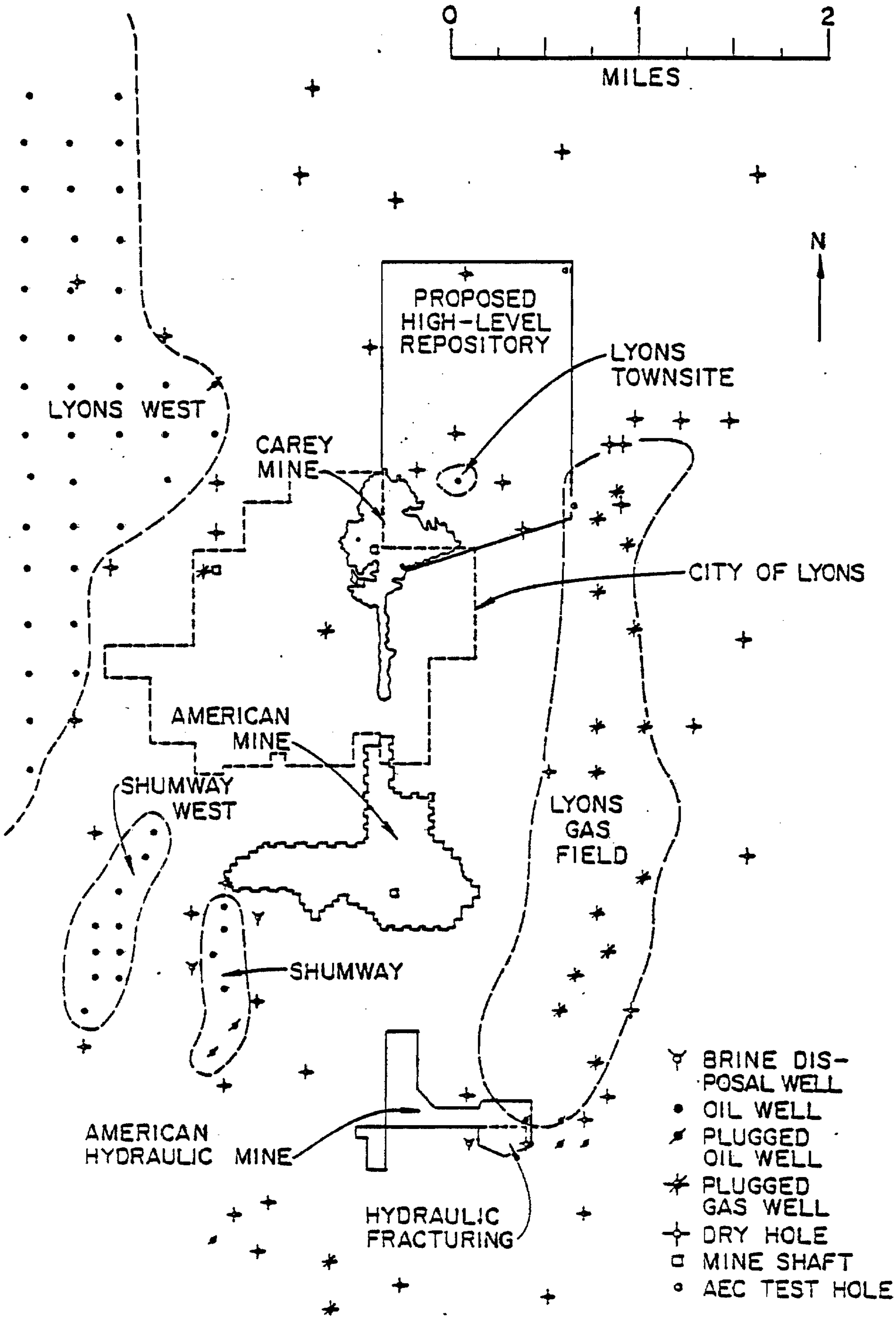
[14]See AEC Authorizing Legislation Fiscal Year 1972, Hearings before the JCAE, Part 3, 1971, pg. 1349-1378.

[15]See AEC Authorizing Legislation for Fiscal Year 1972, Project 72-3.

[16]See SECY-2271, High Level Waste Management, February 2, 1972.

[17]See Memorandum, W. B. McCool to R. E. Hollingsworth, "Program Review: High Level Waste Management," February 7, 1972.

[18]See SECY-2333, High Level Waste Management, February 24, 1972.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1
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WEST
LYONS
GAS
FIELD
SHUMWAY
AMERICAN
HYDRAULIC MINE
HYDRAULIC
FRACTURING
BRINE DIS-
POSAL WELL
OIL WELL
PLUGGED
OIL WELL
PLUGGED
GAS WELL
DRY HOLE
MINE SHAFT
AEC TEST HOLE

FIGURE 2

were established. In large part because of the objections of the Director of Regulation, the change in policy was rejected by the Commission.[19]

Nevertheless, the RSSF concept was not to be implemented. In September 1974, a draft environmental impact statement on the project was issued. Comments received from environmental groups and from State and local governments were generally critical. The coup de grace, however, was delivered by the Environmental Protection Agency. In its comments EPA concluded:

> The development of an environmentally acceptable system for permanent disposal of mmercially generated radioactive waste would appear to be a high priority program that is essential for the development of nuclear power. However, the draft statement does not contain adequate description of a program to develop such a permanent disposal system, nor does it reflect either the priority attached to this overall program by the AEC nor an indication of the resources required. Because of the overwhelming need to develop an environmentally acceptable ultimate disposal method and the realization that there is a risk of failure in any research and development effort, we believe that work on promising alternatives should be pursued concurrently.
>
> A major concern--the employment of the RSSF concept--is the possibility that economic factors could later dictate utilization of the facility as a permanent repository, contrary to the stated intent to make the RSSF interim in nature. Economic factors would consist mainly of the fiscal investment attendant to its construction and the activities which arise in the commercial segment of the economy to support its operation. Since there are controlling environmental factors that must be considered before final disposition of the RSSF, it is important that these factors never be allowed to become secondary to economic factors in the decisionmaking process. Vigorous and timely pursuit of ultimate disposal techniques would assist in negating such a possibility.[20]

The draft environmental statement received EPA's lowest category of evaluation. Signficantly one of the first actions taken by Robert Seamans after he became Administrator of ERDA was to withdraw his request for funds to build the RSSF. Like the Lyon's salt mine before it, the RSSF was officially dead.[21]

This historical narrative of the AEC's involvement in radioactive waste management is presented to provide a summary of what transpired in the past. Given this outline we can now discuss the broad themes of waste management policy.

Underlying Themes of Waste Management Policy

Two themes run--sometimes subtly and sometimes starkly--through the history of the AEC's development of waste management policy. First, is a strong sense of confidence that technological means are available to handle the problem of storing radioactive wastes.

For instance, Dr. J. A. Leiberman, Chief of the Environmental and Sanitary Engineering Branch of the Reactor Development Division, testifying before the Joint Committee on Atomic Energy, as early as 1959, said that:

> Although one has to be careful to distinguish between aspiration, reality, and speculation, it is my strong feeling that the development program has thus far found [technical] solutions to some of the waste problems ...and at least indicated solutions to others."[22]

Dr. Frank Pittman, Director of the Division of Waste Management and Transportation told an audience of the American Nuclear Society in 1972: "We do have today (in the RSSF) the answers

[19]See SECY 74-222, Policies for Management of Commercial High Level Waste, November 16, 1973.

[20]EPA response to Draft WASH-1539, Nov. 15, 1974, (unpublished).

[21]Letter from R. C. Seamans, Jr., to Honorable John O. Pastore; April 9, 1975.

[22]Speech by Frank Pittman to the ANS, November 16, 1972, reprinted in AEC press release S-18-72, pg. 2.

needed for safe management of commercial high level radioactive waste."[23] John Bartlett of the Waste Alternatives Evaluation Program at the Battelle Pacific Northwest Laboratory told the author: "There is no technical problem, the waste can be managed; the crucial problem is public reception of radioactive material." Even the worst blunder in waste management history, the Lyons' Project, was theoretically possible. Bill McClain, the ORNL mining engineer on that effort, was asked by the author whether the laboratory could have handled the problems in Kansas. He replied: "Of course, it was technologically possible." One gets a strong impression, then, from reading the public record and from talking with AEC (now ERDA) personnel: if they (AEC/ERDA Technical experts) were just given enough money and left alone they would solve the "problem" expeditiously and to virtually everyone's satisfaction.

Interestingly, this position is held despite demonstrated failures and the fact that past technological solutions to what must be regarded as a permanent problem have been temporary at best. Again, the experience at Hanford illustrates the point. By the early 1960's, it became increasingly clear that the optimism expressed by Dr. Lieberman at the 1959 Joint Committee hearings was premature. The carbon steel tanks were being corroded at a faster rate than initially anticipated. Thus, a decision was made in 1965 to evaporate completely the waste solutions; the resulting salt cake not only would not leak, but also it would seal up any holes in the tank. Yet, as the Natural Resources Defense Council noted in their petition for NRC licensing of ERDA's high level waste storage facilities:

> Eliminating the excess liquid has to a great extent also ended ERDA's ability to remove the waste from the tanks since as damp solids the waste can no longer be pumped hydraulically out of the tanks. Moreover, liquid cannot be reintroduced into many of the tanks to resuspend the waste since to do so would almost certainly result in substantial leaks to the ground.[24]

While the alternative of mining the waste out does exist, that technique is beset by a number of problems: a remote control system for mining would have to be developed; efforts would have to be made to reduce airborne releases; the material is difficult to deal with; and there is no place to send the material once removed. Thus, while ERDA maintains that it has several viable alternatives to choose from, the record suggests that the technological fix of solidification may be temporary at best. It, too, has engendered problems for the future.

In pointing to the in-tank-solidification program at Hanford, we by no means wish to suggest that it ought not to be undertaken. Rather, we wish to point out that the record only demonstrates the AEC's (now ERDA's) ability to devise temporary expedients; the explicit faith that permanent solutions are possible may very well be misplaced.

Another, related, theme runs through the history of waste management policy. Compared to the analysis of the technological issues involved, little attention has been paid to the non-technological aspects of the problem. This has been the case in two respects.

First, very little sustained analysis has been given to how the technological system will be implemented. In all of the vast material generated by the AEC in support of its various plans, one is hard put to find any discussion of such basic issues as: how will the organizations needed to operate the system be managed to reduce the chance of error; what will be the consequences of going from a small scale operation to a full-blown one; how are the resources, financial and otherwise, needed to sustain the safe operation of the facility guaranteed? A myriad of other, equally significant, questions that the AEC had also ignored could be cited in addition to those three.

Second, very little evidence exists to suggest that the AEC seriously considered the so-called "second-order" consequences of a waste management system. These would include the psychological effects of a major accident, the effect on civil liberties and democratic freedom of efforts to preserve the integrity of the disposal site, and the general issue of foreclosing future options.

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[23] Speech by Frank Pittman to the ANS, November 16, 1972, reprinted in AEC press release S-18-72, pg. 2.

[24] NRDC "Memorandum of Points and Authorities in Support of the Nuclear Regulatory Commission Licensing of the Energy Research and Development Administration's High-Level Waste Storage Facilities under the Energy Reorganization Act of 1974," pg. 18.

Together, confidence in technological virtuosity and neglect of non-technological aspect has given rise to and sustained the impression that a technological fix exists and all that had to be done was to discover it.

At this point the concept of a belief in a technological fix must be clarified. By it we mean a belief that problem-solving in waste management is dependent merely on additional doses of technology. Belief in a technological fix circumscribes artificially and erroneously the boundaries of analysis. A belief in a technological fix arbitrarily excludes factors that can reasonably be said to be part of the problem.

Of course one can posit circumstances under which the waste management problem could ignore the non-technological factors, for instance, institutional questions of implementation. If the solution could guarantee the complete isolation of the waste indefinitely then a bounded technological fix could be quite conceivable. Yet, for any such solution to be adopted, as opposed to proposed, two conditions must be fulfilled. First a high degree of agreement must exist as to how the important parameters of the system, i.e., degree of isolation, are to be measured: there has to be a common, accepted, metric of evaluation. Second there must be a strong consensus over what operations lead to the "correct application of the metric," i.e., what tests accurately measure the degree of extended isolation of the waste. In the real world, neither of those two conditions are likely to be fulfilled.

Implicitly, the AEC (now ERDA) technical personnel and decision-makers recognize the inviability of a technological fix. This prompts their complaint that the system is too open. They complain that environmentalists are irresponsible; politicians are simply trying to grab headlines to be reelected; and the general public is uninformed and irrationally fearful about things nuclear. If these extraneous influences were removed, then something could be accomplished, i.e., uncertainty could be resolved subjectively and a technological solution could be implemented (imposed).

It is not hard to see why the AEC directors strained to decouple the technological core from other aspects of the system. To succeed in doing so-in effect to simplify the problem--conserves such scarce organizational resources as time, thought, and money. Moreover, to consider other aspects of the problem would have forced the agency outside the bounds of its expertise, of its specialization, of what the sociologist Robert Morton called its trained incapacity.[25] To accept the notion that a technological fix is not possible is ultimately to agree that the control of the problem solving effort should be shifted away from the AEC. It is hardly surprising that strenuous efforts have been and are being made to preserve the illusion of a technological solution.

Institutionalizing Belief in a Technological Solution

Early thinkers on waste management recognized that radioactive waste had to be managed in ways altogether different from other industrial wastes. The idea of dumping the waste into nearby bodies of water was, for example, rejected almost out of hand. Moreover, the record indicates that as late as 1955 the AEC had not succumbed to the easy assumption of a technological solution. For instance, A. E. Gorman of the Reactor Development Division speaking about the AEC Production Facilities to the First National Academy of Science Advisory Committee on Waste Disposal, said:

> Looking backward we know of the mistakes that many industries made in assuming that the disposal of waste was simply a backdoor problem that any one could handle. To some extent because of our geographically isolated locations, it had been possible to sweep the problem under the rug, so to speak. But those of us who are close to it are convinced we must face up to the fact that we are confronted with a real problem.[26]

Dr. Leiberman of the Division of Operational Safety noted, "I certainly hope I can disabuse you of the idea that we have any solution that will solve immediately the problems of waste disposal."[27] Yet, if that NAS study began on a note of caution it ultimately provided the major support for the technological optimism that developed in the agency. Although the writers of the NAS report were careful to note the need for further research they stated categorically

[25] See R. Merton, Social Theory and Social Structure, (Free Press, N.Y.; 1968) for an explanation of this idea first advanced by Thurnstein Veblen.

[26] 1957 NAS Report, pgs. 16, 17.

[27] Ibid., pg. 34.

that "the committee is convinced that radioactive waste can be disposed of safely in a variety of ways and in a large number of sites in the United States."[28] Further, they stated that "disposal in salt was the most promising method for the near future."[29] The consequences of such judgments have been great. As someone who has been in the waste management program for a number of years said in an interview, "The NAS report did instill a sense of complacency in the minds of the people dealing with waste management. In part because of it we felt that a solution would be avaiable whenever we needed it." However, it is clear that the NAS study did more than simply instill confidence that waste disposal could be accomplished. It also established the boundaries of the problem. It suggested that all that is required is a technological fix.

The fundamental premise was reinforced in an extended set of hearings before the Joint Committee on Atomic Energy starting in January, 1959. The hearings opened with a statement by Abel Wolman of Johns Hopkins University. Wolman refused to minimize the problems of waste management. He noted:

> We have to have continuity of government supervision whether long or short, whether strong or weak. This is not a problem, in other words, which can be tackled from the standpoint of temporary expedience. It is a problem which will require deep governmental supervision, a...very long and continued uninterrupted supervision over the fate and location of these materials.[30]

Nor did Wolman suggest that the problems were simply technological.

> It is a rather interesting if subtle observation that in conversation with industrialists interested in nuclear fission power they consider the waste problem to be quite unimportant I believe for psychological reasons. It is unimportant to them because they are not responsible for its management and hence its cost.[31]

Wolman's testimony led Representative Chet Hollofield to comment:

> So it would be accurate to say that the problem of permanent disposal of high level waste has not been solved; that it is in the state of suspension; that we are holding these high level wastes to the extent of many millions of gallons in temporary custody and that no decisions have been made as to the final disposal of the high level wastes.[32]

However, those notes of caution and skepticism were virtually the only ones to be heard as the hearing progressed. One expert after another from the AEC, from the National Laboratories, and from industry, testified that a technological solution to the problem was possible and was, in fact, the only aspect of the question that needed to be addressed. Their approach is typified by the comments of Herbert Parker, the Manager of the Richland Facilities. When asked how long he though the tanks at Richland would last, Parker replied:

> I will answer that question by saying that for a longer time than any operation heretofore contemplated by man, these wastes will have to remain isolated from the environment and until the time we create a better way the isolation will be in tanks of this character. This does not mean it will have to be in this particular tank. In other words if the tanks we have turn out to have a life of 50 years, it will be very simple to be prepared at the right time with an alternative set of tanks and pump the liquids into the new tanks. We have extensively moved the liquid into the new tanks. We have extensively moved the liquid from one tank to another and are persuaded we can do this operation with perfect safety.[33]

Although Parker does not say so explicitly, the tenor of his statement when read in its entirety suggests that he sees little wrong with maintaining that strategy of continual maintenance into

[28]Ibid., pg. 3.

[29]Ibid., pg. 6.

[30]1959 JCAE hearings, pg. 9.

[31]Ibid., pg. 11.

[32]Ibid., pg. 10.

[33]Ibid., pg. 165.

the indefinite future. At no point in his testimony does Parker even remotely consider the nontechnological implications for his strategy of waste management. What sort of guarantees need to be devised to insure the existence of spare tanks one hundred or two hundred years into the future? What kind of organizational requirements are necessary to monitor the tanks for leaks and to carry out the shifting of liquid from container to container? Parker's views probably represent an extreme endorsement of a technological fix for waste management. The other witnesses while more subdued in their views are clearly philosophically aligned with the position which Parker had championed.

The cumulative impact of the NAS report and the Joint Committee hearings was to legitimate a circumscribed technological approach to waste management. Over the years it evolved into an official doctrine of the AEC. There is no evidence that its validity was ever seriously questioned or even reassessed. More significantly, the search for a technological solution has persisted and the belief in the efficacy of a technological fix has been maintained, often in the face of disconfirming evidence.

In particular, the AEC continued to pursue a technological fix despite evidence that nontechnological factors are an integral part of the waste management system. The approach taken in dealing with the leaks at Hanford illustrates that point well. The tanks' potential for leaking compelled the operators to implement a system to detect failures in the tanks. The system was highly routinized, volume levels were measured by technicians and compared against previous levels. Although standard operating procedures were enforced to insure the measurements, no procedures were developed to force the requisite comparisons. Thus, it was only a matter time before a leak would go unnoticed. In the spring of 1973, Tank 106T leaked 115,000 gallons into the environment. Excerpts from the chronology contained in the official report on this incident tell the story best.

> On May 2, the first weekly liquid level reading of Tank 106T after the completion the pumping operations was taken it was recorded at 178.9 inches. The information was recorded in the static tank farm inventory log and left on the office desk. The day shift supervisor has stated that he did not review the information because of the press of other duties.
>
> On May 7, the weekly liquid level reading for Tank 106T was recorded at 174.0 inches. information was logged in the static tank farm inventory log in the day shift supervisor's office. He did not review it.
>
> On May 14, the weekly liquid level reading for 106T was recorded at 167.9 inches. The information was logged in the static tank farm inventory log. It was not reviewed by the day shift supervisor.
>
> On May 21, the weekly liquid level reading for 106T was recorded at 160.4 inches. The information was logged in the static tank farm inventory log. The day shift supervisor did not review it.
>
> On May 30, the weekly liquid level reading was recorded at 152.7 inches. The data was logged on the static tank farm inventory log. The day shift supervisor did not review it.
>
> On June 4, the weekly liquid level reading for Tank 106T was recorded at 149.2 inches. It was logged in the static tank farm inventory log. The day shift supervisor did not review it.

Similar failures took place in the dry well monitoring system that was a redundant back up for the volume measuring system. Thus, the leak which began on April 20 was not confirmed until June 6, a period of 6 weeks.[34]

After the leak of Tank 106T, a set of new procedures were adopted. Liquid level measuring instrumentation was computerized; readings were made more frequently. Tank transfers were monitored more precisely. "A rigorous policy of operating equipment according to the procedure was implemented to insure compliance with approved procedures."[35] Several organizational changes were carried out as well. Management responsibility was consolidated; internal audits were

[34]<u>AEC Report on the Investigation of the 106T Tank Leak at the Handord Reservation</u>, June, 1974, pg. 51-57. (106T Report)

[35]WASH-1539, pg. III, 2-3.

reenforced; a division of quality assurance and safety was created; more aggressive management was recruited.

It is hard to assess the effectiveness of those changes. The few years in which they have been in operation is hardly time for a fair test. Nevertheless, they do seem to have performed well. Yet it is clear that the changes do not treat the root causes of the failure to detect leakage in the 106T Tank. That failure was due to non-technological factors. In the words of the official report:

> There was no effective redundancy in the system to assure that a leak undetected by those primarily responsible for detection would be detected by somebody else, or to alert management's attention to any breakdown in the system.[36]

Moreover, by increasing the technological complexity of the detecting system without increasing the assurance of compliance in the non-technological elements needed for implementation, i.e., without assuring that workers follow the new procedures better than they did the old, the overall reliability of the system is likely to decrease. Such an outcome is almost an inevitable result of thinking that focuses primarily on technological solutions.

The pattern of behavior at Hanford is really not atypical. One could just as easily point to the operations in the Lyons' Project, and in the RSSF. In each case, directors focused attention primarily on the technological aspects of the endeavor and largely ignored the nontechnological issues and concerns. In the end, those latter factors largely determined the outcome. Experience should have taught the AEC directors a lesson: their vision in dealing with waste management problems had to be broadened. Only recently has there been evidence that such lessons have been learned.

Consequences of Maintaining a Faith in a Technological Solution

The persistent faith in a technological fix has produced a myopic vision of the waste management problem. In theory, as well as in reality, the boundaries of the waste management "system" have been severely circumscribed. This constrained view of what must be considered in designing a waste management system has resulted in a number of significant distortions.

First, the waste management system is implicitly conceived of as being self-implementing. Those who believe in a technological fix strive to eliminate the human factor-an element which, it is generally held, can only produce noise. Yet, time and time again, persons interviewed in preparing this report stated that the weakest link in a waste management system will be the human one. Significantly, they believe that a human failure such as the one that took place in the 106T Tank leak at Hanford could happen again. Nonetheless, there seems to have been little consideration by the AEC of what leads to such errors or how they might be forestalled in the future. The only consideration of such issues that the author encountered in his interviews is quite superficial. Those views of how to treat the "weakest link" in the system may not fully reflect AEC (ERDA) thinking. They may, however, reflect the degree of sustained consideration which has been given to this question.

A second distortion that has arisen because of faith in a technological fix is the very high discounting of factors which may be affected indirectly by the system. Complex decision-making is difficult. Rules of thumb have to be adopted to simplify problems that are seemingly intractable because of significant gaps in the knowledge base. Judgments have to be made about which factors to consider and which others to ignore.[37] Decision-makers who view a problem through the rosy lens of a technological fix have made, and are likely to make in the future, their judgments in a particular way. Factors associated with technology's primary capacity such as economic growth, safety, efficiency, and perhaps even environmental consequences are given weight; factors associated with technology's indirect effects such as the impact on the social system or its implications for civil liberties are highly discounted.

Ignoring such indirect effects, might be eminently sensible if there were basis for believing that indirect effects are, in fact, negligible. Unfortunately, the issue was never faced by the AEC, for believing in a technological fix predisposes those decision-makers to accept as negligible what is in fact really problematical. Such acceptance is facilitated because secondary impacts are hard to quantify. They are not amendable to easy inclusion in a cost/benefit

[36]106T Report, pg. 6.

[37]See Cyert and March, Behavioral Theory of a Firm, McGraw-Hill, N.Y., 1964.

analysis. In essence, then, these indirect consequences of technology are often banished to a never, never land where they languish unheard and ill considered. If the history of other complex technological systems had not demonstrated that those secondary effects can be significant, concern about discounting them highly in designing a waste management system would be muted. However, the record from the past does show that the strategy of a "conservative" design philosophy should be adopted in all aspects of the construction of a waste management system and not merely in the technological components.

Still another consequence of the belief in a technological fix is that it reinforced factors that reduced the incentive to devote scarce organizational resources to solving the waste problem. Had not the AEC's vision of the issue been conditioned by a belief in a technological fix, the cost considerations and the location of waste management at the end of the fuel cycle would not have had the impact they did in facilitating postponement of a vigorous attack on the problem. The influence of these factors is subtle but nonetheless real.

Consider first the question of cost. Compared to the cost of other parts of the fuel cycle and particularly to the capital cost of reactors, the cost of even an extraordinarily elaborate waste management system is quite low. In 1959, in hearings before the Joint Committee on Atomic Energy, the cost was estimated to be considerably less than a fraction of 1% of the total generation cost of electricity.[38] Fifteen years later, while the "costs are very much higher than previously had been assumed they are still not at the point where they have an adverse affect on comparative economics of nuclear versus fossil fuel."[39] Although precise figures cannot be given now, estimates place the capital costs of the system at considerably less than 1% of the total investment for 200 reactors and their associated fuel cycle facilities. According to one estimate, approximately 0.06 mills per kilowatt hour out of a total of 25.6 mills per kilowatt hour cost of electricity from nuclear power would go for waste management.[40]

Belief in this low cost combined with an optimistic view of what the solution to waste management entailed allowed policy makers to neglect that part of the fuel cycle while developing other parts. Efficient waste management could be bought only by imposing substantial costs at the point of electricity generation or reprocessing. It is more cost effective to optimize those parts of the system and to settle for suboptimization at the final waste management step. Thus, efficiency in waste management could never be bought at the expense of efficiency in reactor operations or reprocessing. It is not a large step from not worrying about optimizing a portion of the system to worrying about it hardly at all.

That waste management represents the final step in the system has also undoubtedly influenced people's approach to the question. If the attitude prevails that a solution can be willed into being when it is required, then there is little incentive to pursue it vigorously in the meantime. Too many, more immediate tasks have to be accomplished. It is not uncommon for people to say even today that the waste management issue is exaggerated. After all, we are told, we do not have any reprocessing plants operating; therefore, we do not have a waste management problem.

However, the most serious consequence rising from a faith in a technological fix is that it provides a rationale for decoupling the question of waste from the rest of the nuclear power system. By definition, a technological fix implies that a bounded solution can be implemented, one that by design does not have effects outside the technological core of the system. It is an easy transition from believing that a waste management system will not have indirect social impacts to believing that it will not have any impact on the rest of the nuclear fuel cycle. Once that transition is made, it is again an easy step to separate the question of waste from the rest of the nuclear power system.

Such fragmentation is hardly a rare phenomenon; it is caused routinely by a number of conditions such as budgetary constraints or short time horizons. The isolation of the waste management issue, however, was clearly compounded by the belief in a technological fix that allowed organizational decision makers to adopt a simplified vision of what is required to solve the waste management problem. Although intimately associated with a number of elements in the fuel cycle, waste management was never treated as part of an integrated whole. As a result any attention that was given to waste management was wholly because of its intrinsic interest as a technological problem.

That appeal however was often very low. At the highest levels there were no commissioners particularly interested in the problems of waste management; with the exception of Commissioner

[38] 1959 JCAE hearings, pg. 2352.
[39] ERDA-33 Nuclear Fuel Cycle, March 1975, pg. 46.
[40] Ibid, Chart 10.

Thompson, never in the history of the AEC did that area have a lead commissioner who championed its needs in the same manner that James Ramey pushed reactor development or as Glenn Seaborg pushed physical research. For most of the commissioners, waste was simply unpleasant and unglamorous. For example, Dixie Lee Ray, according to two persons interviewed would simply "turn up her nose" when the subject was mentioned in meetings. Commissioner Larson was assigned the task by Ray, but he had a number of other assignments of greater interest to him. Ray then tried to assign the area to Commissioner Anders; he did not want to get involved.

Nor could the cause of waste management be sustained through the skillful use of internal politics by personnel at lower levels. For them to pursue the issue intensely hardly made much sense. Grand careers were made in reactor development where the organization's resources were committed, not in waste disposal. Moreover, waste management also seemed to lack the intellectual challenges of reactor research or high energy physics.

In short, because faith in a technological fix facilitated the fragmentation of waste management from the rest of the nuclear fuel cycle, waste management literally became a residual category. Authority, and therefore responsibility, was diffused throughout the organization. Only after considerable prodding from outsiders did the AEC take steps to reorganize its waste managment program.[41] In 1970, the Division of Waste and Scrap Management and Transportation was formed. However, even that new organizational base did not lead to more favorable treatment. Budget allocations remained almost pitifully small.[42] (See Figure 3) Waste management, as the ERDA Task Force on the Nuclear Fuel Cycle correctly observes, remained neglected.[43] (See Figure 4)

In recent years, the failure of fragmentation has been made clear. Nuclear industry spokesmen complain about the uncertainties of the back end of the fuel cycle that were caused by the AEC's developing the different elements sequentially rather than having integrated them into a whole. Nuclear critics refused to accept the AEC's word as they now refuse to accept ERDA's word that technological solutions are at hand. In their minds, it is not optimism but blind unthinking faith which underlines the AEC's and now ERDA's arguments that we need not halt nuclear development until a solution to the waste problem has been found. Thus, it seems that past attempts to simplify the problem by focusing on the technological side alone have led only to greater complications in the present.

Lessons to be Learned

While the thrust of this essay has been critical of the way waste management policy has been conceptualized, its arguments should not be interpreted as an effort to blame individuals for actions they have taken in the past. Pointing the finger or passing out black hats is hardly a productive endeavor in the best of circumstances; but in this case recriminations are even more unwarranted then in most.

The failures of vision which plague waste management decision-making are deeply rooted in the American approach to technological development. In the late 1830's Alexis de Tocqueville remarked on how eagerly Americans adopted innovations. That faith in technological progress had remained an integral part of the American character. It is hard to fault an agency for being in tune with that fundamental spirit.

However, in recent years evidence has accumulated that calls into question the uncritical faith of the technological fix. Nuclear agencies, as well as Congress, ought to reassess their approach to problem solving. That reconsideration will, unfortunately, be painful. Long held traditions and patterns of behavior rarely are altered easily. There are costs--perhaps heavy ones--to be paid. However, it is hard to imagine that any other course of action can yield positive results in the long run. Continued faith in a mythical easy technological fix can push the nuclear agencies only futher outside the bounds of reality.

The difficulty of shifting the way the waste problem is conceptualized can be eased if the ERDA and NRC were to open themselves to interested outsiders, particularly to those who may hold different views about which courses of action to adopt. Past AEC practices of virtually ignoring critical outsiders, need to be reconsidered. Broad participation in decision-making does not guarantee good outcomes, but it can spotlight flawed conceptualizations of the problem. Had such institutionalized criticism existed in the past, the AEC might not have held to its faith in a technological fix as long as it did.

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[41] See 1968 GAO Report, pg. 18-20.

[42] Figures supplied by Alex Perge, ERDA's Division of Nuclear Fuel Cycle and Production.

[43] ERDA-33, Chart 6.

FIGURE 3

Summary of Waste Management Funding (Millions)

	FY 1961	FY 1962	FY 1963	FY 1964	FY 1965	FY 1966	FY 1967	FY 1968	FY 1969	FY 1970
Nuclear Materials Program										
A. R&D Costs	$ 0.5	$ 1.1	$ 1.4	$ 1.5	$ 1.8	$ 1.4	$ 1.3	$ 1.7	$ 1.8	$ 2.0
B. All Other Operating Costs	3.3	3.3	3.3	4.6	4.3	5.7	7.8	13.7	17.3	18.5
C. Plans and Capital Equipment Obligations	1.9	0.4	5.0	4.1	5.6	10.8	9.5	2.1	8.7	7.5
Subtotal Nuclear Materials Program	$ 5.7	$ 4.8	$ 9.7	$ 10.2	$ 11.7	$ 17.9	$ 18.6	$ 17.5	$ 27.8	$ 28.0
Reactor Development Program										
A. R&D Costs	$ 3.5	$ 3.2	$ 3.1	$ 3.0	$ 3.8	$ 3.3	$ 2.7	$ 2.5	$ 2.9	$ 2.8
B. All Other Operating Costs	-	0.8	0.3	-	-	-	-	-	-	-
Subtotal Reactor Development Program	$ 3.5	$ 4.0	$ 3.4	$ 3.0	$ 3.8	$ 3.3	$ 2.7	$ 2.5	$ 2.9	$ 2.8
Waste Management Program										
A. R&D Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
B. All Other Operating Costs	-	-	-	-	-	-	-	-	-	-
C. Plant and Capital Equipment Obligations	-	-	-	-	-	-	-	-	-	-
Subtotal Waste Management Program	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Fuel Cycle R&D Program										
Waste Management (Commercial)										
A. Operating (All R&D) Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
B. Plant and Capital Equipment Obligations	-	-	-	-	-	-	-	-	-	-
Subtotal Fuel Cycle R&D Program	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Weapons Materials Production										
A. Operating (R&D) Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
B. Operating (Other) Costs	-	-	-	-	-	-	-	-	-	-
C. Plant and Capital Equipment Obligations	-	-	-	-	-	-	-	-	-	-
Subtotal Weapons Materials Production	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Totals										
A. R&D Costs	$ 4.0	$ 4.3	$ 4.5	$ 4.5	$ 5.6	$ 4.7	$ 4.0	$ 4.2	$ 4.7	$ 4.8
B. All Other Operating Costs	3.3	4.1	3.6	4.6	4.3	5.7	7.8	13.7	17.3	18.5
C. Plant and Capital Equipment Obligations	1.9	0.4	5.0	4.1	5.6	10.8	9.5	2.1	8.7	7.5
Grand Total	$ 9.2	$ 8.8	$ 13.1	$ 13.2	$ 15.5	$ 21.2	$ 21.3	$ 20.0	$ 30.7	$ 30.8

SUMMARY OF WASTE MANAGEMENT FUNDING (MILLIONS)

	FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976	Transition Quarter	FY 1977	Cum. FY 1971 FY 1977
I. Nuclear Materials Program									
A. P & D Costs	$ 1.5	$ 1.8	$ 1.6	$ 1.8	$ -	$ -	$ -	$ -	$ 6.7
B. All Other Operating Costs	20.3	21.9	24.3	33.7	-	-	-	-	100.2
C. Plant and Capital Equipment Obligations	9.9	24.0	11.5	44.4	-	-	-	-	89.8
Subtotal Nuclear Materials Program	$ 31.7	$47.7	$37.4	$79.9	$ -	$ -	$ -	$ -	$196.7
I. Reactor Development Program									
A. P & D Costs	$ 1.7	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1.7
B. All Other Operating Costs	--	-	-	-	-	-	-	-	-
Subtotal Reactor Development Program	$ 1.7	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1.7
I. Waste Management Program									
A. P & D Costs	$ -	$ 4.4	$ 5.0	$ 9.9	$ -	$ -	$ -	$ -	$ 19.3
B. All Other Operating Costs	-	1.3	1.6	2.3	-	-	-	-	5.2
C. Plant and Capital Equipment Obligations	-	1.6	0.2	2.6	-	-	-	-	4.4
Subtotal Waste Management Program	$ -	$ 7.3	$ 6.8	$14.8	$ -	$ -	$ -	$ -	$ 28.9
V. Fuel Cycle P & D Program Waste Management (Commercial)									
A. Operating (All P & D) Costs	$ -	$ -	$ -	$ -	$ 9.4	$ 11.9	$ 3.4	$ 60.0	$ 84.7
B. Plant and Capital Equipment Obligations	-	-	-	-	0.5	0.6	0.2	5.8	7.1
Subtotal Fuel Cycle R & D Program	$ -	$ -	$ -	$ -	$ 9.9	$ 12.5	$ 3.6	$ 65.8	$ 101.8
V. Weapons Materials Production									
A. Operating (P & D) Costs	$ -	$ -	$ -	$ -	$11.5	$ 16.8	$ 4.9	$ 28.1	$ 61.3
B. Operating (Other) Costs	$ -	-	-	-	42.4	52.7	14.5	63.7	173.3
C. Plant and Capital Equipment Obligations	-	-	-	-	31.7	83.6	24.2	119.9	259.4
Subtotal Weapons Materials Production	$ -	$ -	$ -	$ -	$85.6	$ 153.1	$ 43.6	$211.7	$ 494.0
I. Totals									
A. R & D Costs	$ 3.2	$ 6.2	$ 6.6	$ 11.7	$20.9	$ 28.7	$ 8.3	$ 88.1	$ 173.7
B. All Other Operating Costs	20.3	23.2	25.9	36.0	42.4	52.7	14.5	63.7	278.7
C. Plant and Capital Equipment Obligations	9.9	25.6	11.7	47.0	32.2	84.2	24.4	125.7	$360.7
Grand Total	$ 33.4	$55.0	$44.3	$ 94.7	$95.5	$ 165.6	$ 47.2	$277.5	$813.1

FIGURE 4

	"FRONT END"					"BACK END"				
	EXPLORATION MINING MILLING	CONVERSION	URANIUM ENRICHMENT	UO_2 FUEL FABRICATION	REACTOR OPERATIONS	SPENT FUEL STORAGE	SPENT FUEL REPROCESSING	MIXED OXIDE FUEL FABRICATION	RECYCLE IN REACTORS	WASTE HANDLING STORAGE DISPOSAL
BASIC TECHNOLOGY IN HAND?	YES	YES	YES	YES	YES	YES	YES	YES	YES	?
TECHNOLOGY BEEN DEMONSTRATED ON COMMERCIAL SCALE?	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO
ADEQUATE NATURAL RESOURCES BEEN LOCATED?	NO	-	-	-	-	-	-	-	-	?
CAPITAL FUNDING AVAILABLE FOR NEEDED EXPANSION?	?	N S	?	N S	?		?	?	N S	?
ENVIRONMENTAL PROBLEMS BEEN RESOLVED?	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO
SAFEGUARDS PROBLEMS BEEN RESOLVED?	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO
MAJOR LICENSING PROBLEMS BEEN RESOLVED?	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO

Today we have a manageable radioactive waste problem. The legacy of the production facilities is not so large as to be intractable. Every day we continue to create waste without a solution in hand we reduce that manageability. Cost of failure rises exponentially. We begin to substitute faith for performance. In doing so, we may succeed only in producing more heretics and dissidents. It is imperative that such a state of affairs not be allowed to occur. We need to get on with problem solving for waste management. But we need to always be aware that the solution must treat adequately and as precisely as our limited knowledge allows the full range of technological and non-technological issues. In this way, not through more sophisticated public relations and public manipulation, will true public acceptance be found.

THE CREDIBILITY ISSUE

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THE CREDIBILITY ISSUE

To say that the disposition of radioactive wastes constitutes a problem of vast gravity is merely to mouth a platitude. Nonetheless, the statement is useful if only to serve as a springboard to a serviceable definition, which should forestall debate, unnecessary in this context, over particulars. For purposes of this discussion, the following definition is used:[1]

> Radioactive wastes are those radioactive materials which are of sufficient potential hazard that they require special care and which are of no present economic value to the nuclear industry.

While the primary focus of this discussion is on radioactive wastes and not on the total nuclear fuel cycle nor on the nuclear option as compared with others as sources of energy, many of the desiderata are inextricably intertwined. This is nowhere more apparent than with respect to the role of experts. Because nuclear energy, to an extent probably greater than any other issue in our time, embraces a spectrum of scientific disciplines, technical specialties, and economic, political, and social factors, we have witnessed the emergence of a considerable number of experts, with an array of opinions spectacular in their diversity. In commenting on this phenomenon, John Holdren has observed,[2]

> If you laid them all end to end, they'd never reach a conclusion. The fact is that the experts--individuals with appropriate specialized training who have devoted a significant amount of time to aspects of nuclear issue--do not agree about the answers to many of the important questions. They do not agree, for example, about just how toxic plutonium is, nor about the probability of certain kinds of reactor accidents, nor about the adequacy of various proposals for the management of radioactive wastes.

Review of reports and documents, of the testimony of experts at hearings, and of views ascertained through personal interview supports Holdren's observation. There is, nonetheless, and with only minor exceptions, consensus that radioactive waste disposal presents a problem. Alvin Weinberg, David Lilienthal, Hannes Alfven, while representing divergent positions vis-a-vis nuclear energy, nonetheless concur that safety is a prime desideratum both in the interim disposition and the permanent disposal of the radioactive wastes. They, among others prominently identified with the nuclear debate, have emphasized the need for containment, meticulous isolation from people and environment. Among the proposed methods of disposal--geologic, ice sheet, sea bed, and extra-terrestrial, there are clearly specified favorable and unfavorable features. Of common concern, also, is the potential for harm through diversion of fissionable materials for destructive and illegitimate purposes. Because of the likelihood that the concentration of radioactivity in the wastes will remain at a harmful level for many hundreds of years, there is growing awareness that waste management encompasses a myriad of social and moral considerations along with the scientific and technological. Alvin Weinberg has stated, "...the price we demand of society for this magical energy source is both a vigilance and a longevity of our social institutions that we are quite unaccustomed to." He suggests that there is need for a "military priesthood" to guard against misuse of the materials. Hans Bethe[3] similarly acknowledges the necessity for longterm safeguards.

Despite the instances of apparent agreement, opinions vary widely, as Holdren states. Nonetheless, because little knowledge and still less wisdom would be garnered from a point-counterpoint juxtaposition and comparison of the polarized positions, we shall avoid the tiresome rehearsal and reiteration of opinions because they are not only known but predictable along a continuum from pro to con. Moreover, we can only acknowledge the lack of definitive answers to the question of how expert is expert, or the qualification premia that attribute authoritativeness to one position and withhold it from another. The Gradus ad Parnassum by which one attains status

[1] U.S. Congress, Joint Committee on Atomic Energy, 94th Congress, First Session on Assessing the Policies, Plans, and Programs of the Executive Branch for the Safe Storage and Disposal of Radioactive Wastes Produced in the Commercial Nuclear Fuel Cycle, Enclosure B, p. 83, November 19, 1975.

[2] John P. Holdren, "Security, Safeguards, and the Limitations of Decision-Making by Experts," Statement at Hearings on the California Nuclear Initiative by the California Assembly Committee on Energy and Diminishing Materials, November 18, 1975.

[3] Hans Bethe, "The Necessity of Fission Power," Scientific American, January 1976, p. 29.

varies among the disciplines; within fields, there are few universally accepted and respected criteria for professional excellence; and attaining national status in one's field is not necessarily correlated with either stature or excellence. Nonetheless, the temptation to play the role of expert is almost irresistible and opportunities beckon.

Since the array of "experts" on nuclear matters covers a wide range of specialty, authoritativeness, and prestige, what becomes crucial is the ascription of credibility, or whom one elects to believe. At all levels, from the most naive and least informed to the most sophisticated and best informed, the process is one of creditation and, concomitantly, of discreditation. The assignation of credibility, i.e., whom you are prepared to believe, depends on your particular state of credulity, i.e., how and what you believe. And this, more than "objective" criteria, is what is of paramount importance. Here, despite the language, logic, and accoutrements of science that have given a certain aura to the controversy surrounding nuclear power, much depends on faith, scrutiny of which is intended here to provide perspective. For purposes of analysis, we offer the following trichotomy: (a) naive faith in science and technology, i.e., on the part of the public at large; (b) "informed" faith in science and technology, as, for example, on the part of the scientific and engineering community; and (c) fatalistic faith in science and technology.

Naive Faith in Science and Technology

A basic element in (a) is ignorance. In this respect, the public is like W. H. Auden's shabby curate[+]--standing in awe. They don't know, but several hundred years of history stand to convince them that they can thank science and technology for everything that they have come to regard as progress. Just beginning to dawn is the possibility that mankind has been engaged in a Faustian bargain and that there may be prices to pay. This can be seen in other cornucopias, first yielding bounty and then extracting toll. Nonetheless, at least for the present, a prevailing article of faith is that science and technology will go on providing solutions.

So deepseated is this belief that it has become a kind of unarticulated superstition, sometimes in unwonted places. As an example, one might cite the editorial comment in the New York Times on the Secretary of Transportation's decision to permit the Concorde to use certain U.S. airports.[5] Hitherto in vehement opposition to the SST, the Times shelved its ominous predictions and gloomy forecasts of ozone depletion. Instead, the editor suggested that a limited trial would probably do little harm and might, in fact, afford an opportunity for study and technological advancements that would correct the problems. This illustration is intended not to argue the soundness of either Coleman's decision or the Times' position but rather to exemplify an interesting manifestation of the "science-will-save-us" argument that often serves as a foot in the door, or entering wedge. This syndrome prevails vis-a-vis nuclear fission and its attendant problems. The man-in-the-street, baffled by the complexities, many of which fall into the scientific and technical realm, and conscious of his own ignorance, looks unquestioningly to science and technology to solve the problems. In so doing, the public manifests its particular brand of faith. Peter Berger explains why this occurs:[6]

> There remains something in all of us of the childish belief that there is a world of grownups who know. There must be--because we evidently don't know.

This state of not-knowing has been played on skillfully in the nuclear controversy. Using the argument that sophisticated science and technology are involved in such matters, protagonists for nuclear energy have leaned heavily on the prestige of scientific knowhow and technological achievement for answers to any troublesome questions as to reactor safety, waste management, radiological risk, etc. To bolster their respective positions, both sides resort to the argumentum ad nominem, the lists of Nobel laureates, professors, and prominent professionals who agree with them. In the growing debate over nuclear power, whether you believe and whom you believe and what you will believe are irrevocably intertwined.

Scientists' and Engineers' Faith in Science and Technology

Scientists and engineers harbor another kind of faith.[7] Not unlike other professional groups but to a degree more marked, perhaps, they are inclined to exhibit a large measure of confidence

[+] W. H. Auden has been quoted as saying, "When I find myself in the company of scientists, I feel like a shabby curate who has strayed into a room full of dukes."

[5] Editorial, The New York Times, February 5, 1976.

[6] Peter Berger, The Precarious Vision, New York, Doubleday, 1961, p. 83.

[7] To be noted here is the fact that not all scientists and engineers think alike. As has become patently clear with respect to nuclear energy, there are wide divergencies of opinion. Nonetheless, the scientific and engineering communities, as a group, display enough broad areas of agreement to set off their position and approach. This is not due to chance. Studies in the sociology of occupations reveal that certain generalizations about attitudes, values, and preferences can be made with reasonable accuracy.

in their techniques and tools. They start with the premise that insofar as problems are scientific/technical, their skills will ultimately solve them. Their tendency is first to interpret and define probems as though they were scientific/technical, and then to treat those aspects as though they were the whole problem. A. Maslow described this predilection by observing, "If the only tool you have is a hammer, it is remarkable how everything begins to look like a nail." The technical stance defines the problem, whether it be vegetable, animal, or mineral, in technical terms and then makes the confident technical assumption that it can or will be solved technically. This may be unrealistic; it also may be dangerously tautological in that it systematically eliminates elements, factors, and facets that may be quintessential to the problem. The "can-do, everything is under control, just leave it to us" message came through clearly in the November, 1975 Congressional Hearings on the Storage and Disposal of Radioactive Wastes.[8] Effective management of nuclear wastes could, to quote one authority, "be anticipated with confidence." It may be noted that subsequently the Nuclear Regulatory Commission broadened its conception of the task at hand and now recognizes[9] a full range of dimensions, i.e. social, economic, and environmental, as well as technical. This view may be less confident, but it is more realistic and much more consonant with present thinking about the problems.

In general, the Procrustean[10] approach prevails. A certain limited set of assumptions is put forward; they all have to do with specific technical aspects, which are then treated as though they were the sum total of the matter at hand. Actually, preoccupation with a segment to the neglect of the large spectrum can create serious distortion and lead to erroneous conclusions. Inherent in this approach is faith in technology--a faith articulated by Dr. Cecily Cannan Selby, a biologist,[11] during a television debate:

> I do have faith in science and technology, proven faith...There is nothing else that is so strictly and severely regulated. So it is faith in this system, and the faith in the development, the skills and the development of our technology, that some of the unsolved problems will most certainly be solved by the time we have to address them.

In our assessment of the credentials of the experts, we have found reason to infer that professionals are no less susceptible to self-deception than are lay persons. A recent study by the Carnegie Commission on Higher Education[12] provided interesting supporting data. Some 60,000 full-time faculty members were canvassed to ascertain their views on a number of controversial issues such as Vietnam, busing, and the legalization of marijuana. The great preponderance showed an inclination to opt for expediency and to protect their careers. From this, one can reasonably argue that "alarmed self-interest" would play a decisive role with respect to their position on other topics fraught with political implications, such, for example, as nuclear energy. This point is amply corroborated by Roger Revelle, Chairman of the Board of Directors of the AAAS, in his testimony before the House Science and Technology Committee in June 1975. Excerpts from his dialogue with Representative George E. Brown, Jr. of California follow.[13]

> Mr. Brown:...[Dr. Revelle,] you suggest that engineers and scientists should be guaranteed freedom to express their ideas about the probable consequences for society of their discoveries...Is that right?
>
> Dr. Revelle: Yes, sir.
>
> Mr. Brown: What is it that you think inhibits their freedom to express their ideas? How could we give a guarantee other than [that] contained in the Constitution already?

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[8] U.S. Congress, Joint Committee on Atomic Energy, 94th Congress, First Session on Assessing the Policies, Plans, and Programs of the Executive Branch for the Safe Storage and Disposal of Radioactive Wastes Produced in the Commercial Nuclear Fuel Cycle, November 19, 1975.

[9] Marcus A. Rowden, Chairman, U.S. Nuclear Regulatory Commission, Statement on the subject of Nuclear Waste Management before the Joint Committee on Atomic Energy, May 12, 1976.

[10] Procrustes, it will be recalled, was a legendary highwayman, known for tying his victims onto an iron bed, and, as the case required, stretching or cutting off their legs to adapt them to its length.

[11] Dr. Selby is president of Americans for Energy Independence, a lobbying group financed in large part by the nuclear industry. (This information and the quotation are from David Burnham, "Nuclear Energy Has Moral Components, Too," The New York Times, May 9, 1976.)

[12] Cited in Everett Carll Ladd, Jr. and Seymour Martin Lipset, The Divided Academy, New York, McGraw-Hill, 1975.

[13] Richard A. Scribner (Office of Science and Society Programs, AAAS), "Scientific Freedoms and Responsibilities," Science, 5 September 1975, p. 785.

Dr. Revelle:...One example of this, Mr. Brown, is the concern that many atomic scientists developed over the past two decades concerning the effects of atomic radiation. I think, particularly, [of] some scientists in Berkeley [who] were more concerned about these questions than they thought that the Atomic Energy Commission was. They had a hard time getting their views made public without losing their jobs. There are many examples of this kind where the scientists are concerned that what is being done may be dangerous or disadvantageous to the public interest. However, because of the organization constraints that they are under, they might not be able to state [their concerns].

Mr. Brown: That is a very sticky problem. What you are saying is that because many scientists get their support from government, or government-funded private institutions, they are reluctant to speak out in support of policies that would be contrary to the policies being followed by the people providing them with money.

That there are "approved" positions on most such questions cannot be denied. When the proposed Storm King power plant on the Hudson River was under consideration, former New York Representative Richard Ottinger spent two years in the attempt to locate a scientist to testify that, as research had indicated, a bass spawning ground would be endangered.[14] Establishment by the National Academy of Sciences of a Committee on Nuclear Power and Alternate Energy Sources provides a telling case in point. Appointment of Harvey Brooks and Edward L. Gingston[15] as cochairmen and selection of several of its 13 members from the nuclear industry[16] indicate the "establishment" position, toward which the larger community can be expected to gravitate. This is buttressed by the way in which Presidential science advisors are chosen, the process being one of consent and advise-- a kind of bureaucratic counterpart of the self-fulfilling prophecy. The White House selects individuals whose views conform to a particular "official" (but not always articulated) position. This becomes self-reinforcing, since, by the rules of grantsmanship and the unwritten laws of research support, the ripple effect reaches every last laboratory in the nation.

An indicator of the faith in the perfectibility of technology can be seen in a mirror image--of engineers who have questioned the safety of systems and taken a stand against nuclear energy. Regarded as defectors, they have been ostracized by their profession. Treated like pariahs, they find that their records and personal lives are scrutinized for flaws and aberrations. This is because true believers would not forsake a cause. As with religion, dissent is heresy, a sin--to be punished. B. Flanger, past chairman of the Nuclear Power Codes and Standards Committee of the American Society of Mechanical Engineering, attributes the actions of General Electric and Nuclear Regulatory Commission engineers who resigned as an expression of protest and concern to a "messiah complex."[17] He puts forward his own credo: "Based on my own extensive experience in the same field, I do not believe that their internal reports were internally suppressed without adequate evaluation." Mr. Langer expresses faith in the right kind of engineers and appropriate professionals.

> When a judgment is to be made on a technical question, elimination of all persons with any conflict of interest automatically eliminates all those who have any deep knowledge of the subject. Power plant safety is an engineering problem, not a scientific problem. It takes experienced quality-assurance engineers, stress analysts, system designers, metallurgists and other engineers to solve it. The opinions of physicists are worth very little and opinions of biologists are usually worth nothing unless they educate themselves in more relevant disciplines. (Emphasis added)

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[14] Constance Holden, "Public-Interest Advocates Examine Role of Scientists," Science, 4 February 1972, p. 501.

[15] Respectively, former dean of engineering and applied physics and chairman of the board of Varian Associates.

[16] As, for example, the head of the Bechtel group of companies, the executive vice-president of the Exxon Research and Engineering Company, and a top official in the Chase Manhattan Bank of New York.

[17] B.F. Langer, Letters to the Editor, New York Times, April 10, 1976.

The matters of faith, politics, and polarity are discussed at length in this context, not to cast aspersions on the scientific community, nor to impugn their integrity, nor even to challenge the validity of their positions but rather to encourage at least a slight foray into their sacrosanctity. This becomes all the more necessary as issues facing society grow in complexity and involve more and more specialized areas of knowledge, for experts will, in Parkinsonian fashion, proliferate as the occasions arise. It will be imperative that we develop sophistication in assigning credibility. While government officials faced with decisions about radioactive waste management must seek the advice of experts, they must learn to evaluate what they are getting. It is necessary that they recognize the psychological mechanisms and constraints of the social structure that impinge on all of the advice they are getting. These require serious consideration. For responsible decision-makers to adopt one set of beliefs, e.g., such as those put forth by the "in" group of science advisors is to predetermine and prejudice their thought-processes to the possible detriment of the outcome. Administrators must be encouraged to perform enlightened and sophisticated judgments far superseding doctrinaire considerations.

There are several reasons for scientists' and engineers' remarkable reliance on the state of their art. The first is an observation applicable to other professions in some degree. It has to do with the career stake, professional competence and a reputation being achieved through years of preparation. Thus interests become vested. Among scientists and engineers especially, there is, moreover, a strong element of pride of workmanship involved. This would impel one to keep one's long-developed career intact even irrespective of its implications for society. At its pathological extreme, this is Eichmannism, the monstrous perfecting of concentration camps and means to torture and kill innocent human beings. In somewhat milder terms, it is the meticulous doing well of something which, perhaps, should or need not be done at all. While this phenomenon is not limited to the technical community, it seems to be more highly visible here than, for example, in the "softer" disciplines.

That engineers "are often wrong but seldom in doubt" is a cliche bruited about in conference corridors. It simply caricatures an organizational perspective that is germane when evaluating the inputs of engineers to decision-making processes. The phenomenon, called "trained incapacity," was described by Merton[18] as "that state of affairs in which one's abilities function as inadequacies or blind spots." "A way of seeing is also a way of not seeing--a focus upon object A involves a neglect of object B." Richard Hubbard, one of the nuclear engineers who resigned from General Electric as an expression of concern about safety in nuclear plant operation and materials handling, described trained incapacity in real-life dimensions.[19]

> It's a tunnel vision kind of thing. We look very much at instruments. Each of us looks at our own very narrow aspects. I had never even questioned the whole thing for years and years. All I wanted to do is to get that neutron signal into amperes, and I never really looked at what else we were doing.

Trained incapacity causes one to conceptualize the problem at hand in terms of one's own technical discipline and then to proceed with the solution as though the definition actually reflected the full essence and dimensions of the problem. Then follows a kind of QED reduction: to simplicity. The problem has been conceived thus, handled so, and is, therefore, solved. Crudely expressed, this technique consists of shooting the arrow, drawing the target around it, and proclaiming oneself champion for hitting the bull's eye!

There is no dearth of examples; the difficulty lies only in choosing. The following has been selected merely on the basis of expediency: "Energy and the Environment, A Risk-Benefit Approach" was the topic of a seminar co-sponsored by Stanford University Institute for Energy Studies and the Electric Power Research Institute of Palo Alto (November, 1974). Among the participants was Professor Wolf Haefele, a physicist with the International Institute for Applied Systems Analysis in Laxenburg, Austria. Noteworthy here was the way in which the problem was categorized, i.e., as "risk-benefit," thus invoking a particular set of techniques and identifying the "expert," a specialist in systems analysis. This was a remarkable example of shooting the arrow and then drawing the target. Häefele interpreted the entire nuclear energy program as one amenable to a risk-benefit treatment and set forth three main and simple propositions: (1) there is an indefinite amount of benefit to be derived; (2) there is an unlimited amount of threat and risk; and (3) there is an unlimited amount of safeguards and engineering that can be supplied. His presciption was "to put the three dimensions together <u>in a prudent manner in an operational scheme</u>." This solution begs the question, of course, and, in addition, reveals the tacit assumption that this can be accomplished. Even his own unarticulated reservations, that

[18] Robert K. Merton, <u>Social Theory and Social Structure</u>, Glencoe, Illinois, The Free Press, 1949, pp. 153-4.

[19] David Perlman, "What Led Nuclear Experts to Quit," <u>San Francisco Chronicle</u>, February 3, 1976.

there may be dangers not contained by this scheme, come through in technical form. He proposes that a "resiliency indicator" be included in the problem-solving equations, to account for "the stabilities in large organisms that make them capable of absorbing impacts of any kind."

Another example of trained incapacity occurs in the ways a management firm proposes, in a study performed for the Atomic Industrial Forum, to safeguard fissionable material against potential hijackers and terrorists. According to the author of the report, the problem is simply one of "management." Hence, the proposed solution takes the form of hardware and policing. Fuel reprocessing and enrichment plants would be encircled by concertina barbed wire; multiple sensor systems would monitor interior and exterior areas; and anti-helicopter cable nets would shield the sites from above. Materials would be moved in specially-designed trailers, built like armored trucks and equipped with elaborate locking mechanisms. There would be a national radio network in constant communication with each shipment, a national command center having been established to coordinate emergency response activities with military and police forces in case of theft or attack. In addition, a special strike force, similar to SWAT (Special Weapons and Tactics) teams, armed with sophisticated weaponry would stand ready. The problem of safeguarding fissionable material, handled in this way, was made to appear easily soluble within the present state-of-the-art. But this approach not only trivialized the matter out of proportion to its real-life dimensions but also cavalierly disregarded the virtual state of war that would have to prevail wherever the materials stayed or moved.

Somewhat related to faith in the given discipline is the attribution of credibility to individuals representing the "establishment position" within that discipline and, in so doing, accrediting them with a kind of omniscience. Thus, the prominent scientist who has received the Nobel Prize for distinguished contributions in his field is treated like the traditional tree-full-of-owls and accepted as an authority in whatever pronouncements he chooses to make. Herein, we see an opportunity for egregious misuse of credentials, with nuclear physicists offering economic forecasts, political advice, and social judgments. While, as private citizens, such personages have the right to make their voices heard, the prestige their advocacy lends to a particular position is not without its dangers. The aura can and, in many cases, does obscure private prejudice, as well as economic, political, and social naivete.

Although in theory it is possible for experts to remain neutral and to serve as a kind of reservoir of wisdom, in practice, and perhaps especially with respect to nuclear energy, some experts have been inclined to take active partisan roles. They have testified at hearings; they have produced studies and research data; they have engaged in public debate; they have even emerged as columnists in the popular press. In the course of these activities a remarkable phenomenon seems to have occurred; their specialized knowledge becomes all-purpose. This phenomenon is not unique to scientists and engineers nor is it characteristic solely of persons advocating nuclear power. Nonetheless, rather superficial review of writings and testimony suggests that the tendency to ride on their credentials prevails more among them and is more apparent in the nuclear debate than among other professions and on other subjects. This observation is receiving corroboration through systemic analysis by a professional linguist who is participating in a study by the Committee on Nuclear and Alternative Systems for the National Academy of Sciences. On a matter closely related and very pertinent, Cousteau made the cogent observations,[20] based on an international conference on the disposal of radioactive waste, that (a) the only participants who dared to express doubts about the planned operations neither belonged to a nuclear agency nor had anything to gain from atomic proliferation and (b) the pros came from specialists in physics and chemistry, while the cons were expressed by biologists and physiologists. A corollary that might be appended here is that the persons in the con corner are likely to raise questions while those in the pro position are prone to be quick with answers. This kind of across-the-board authoritativeness is especially apparent in the activities of Thomas J. Connolly, a professor of mechanical engineering at Stanford University. Although contributing to a compendium of papers[21] purported to provide a "balanced analysis of the key issues" surrounding nuclear power in general and the California Nuclear Initiative in particular, Connolly's faith in the technology dominated his thinking to the point that his pronouncements became a catechism for economics, international politics, and public policy matters. For example he sets forth numerical energy goals that he says it would be "grossly imprudent" for the U.S. not to follow; he assures the reader that the military program, which has put "more than 10,000 pounds of plutonium into the earth's atmosphere" should provide us the "a basis for confidence in the civilian power sector." His analysis of the "facts" about radioactivity leads him to the well-known albeit socially unacceptable reductio ad absurdum about removing residents from Denver or brick houses. He cavalierly dismisses the need for monitoring radioactive

[20] Jacques-Yves Cousteau, "The Peaceful and Warlike Atoms--Living without Both," The New York Times, August 8, 1976.

[21] Thomas J. Connolly, "Nuclear Technology and the California Nuclear Initiative, Chapter 3 in The California Nuclear Initiative, Stanford University Institute for Energy Studies, Stanford, California, 1976, pp. 65-127.

wastes as nonexistent. Stressing the vagaries of human behavior, he offers the judgment that people have not "reacted strongly" to the discovery that uranium mine tailings were used in some construction, the implication being that the outer limits of risk-tolerance have yet to be tried.

When Connolly testifies before the Warren Committee,[22] his polemic becomes pyrotechnical, especially as regards the various groups supporting the Nuclear Initiative. He discusses their methods and analyzes their tactics. "They know it is easier to attack than to defend." "They make their target the legitimate fears and concerns that people should have about a massive new technology." "They are specialists in sowing doubt." It does not seem to occur to Connolly that his astonishing primer on the principles of propaganda applies to the "Nukes" as well as the "Kooks." His political science analysis ricochets with similar abandon, for his logic suggests that OPEC dollars, which he says represent "billions for tribute to sheikhs and shahs," ultimately find their way to the coffers of terrorists, such as the Palestinian Liberation Organization. Finally, Connolly warns "self-appointed experts" opposing nuclear energy that they are "undermining their own future," since, in his view, they are "sandbagging the entire productive sector of this country" and jeopardizing Social Security retirement systems, and the like. His conclusions indicate his social philosophy and have implications for the democratic process:

> You can take all the groups I have mentioned, place them end to end, and I challenge any one to extract one barrel of oil, one ton of coal, or one kilowatt-hour of electricity. Indeed, one would be hard pressed to find anything useful which they have ever produced. And yet these are the groups, in hearing after hearing across the country, whose advice is being sought on questions of energy policy. We are witnessing an Alice-in-Wonderland kind of madness which this country cannot indefinitely sustain.

The current controversy over nuclear energy appears to be aggravating a dilemma associated with the role of the scientist in society. From ancient Greek times on, the scientist has been accorded a unique place. Respected for his pursuit of knowledge for knowledge's sake, expected to maintain objectivity, he now find himself called upon to deliver certain types of products and services. And often, even in the face of his noble intent, these can be used in such fashion as to render them far from neutral. Thus, will-nilly, he can find himself cast in an advocacy or adversary role, even though he may himself acknowledge that science is not omniscience and that there is no one unassailable "scientific" truth. Under less noble circumstances, it is well known, as we have shown in the foregoing pages, that experts do have their biases, with "rationality" always residing on the <u>in</u> side and "rhetoric" on the <u>out</u> side.

By way of concluding this section on the faith of scientists and engineers, it should be noted that trained incapacity is a universal human characteristic. It is a kind of self-enforcement of attitudes, views, and values distilled from accumulated, and, as a matter of cognitive economy, selectively applied experience. While possibly more apparent in some sectors than in others, this phenomenon is not limited to any profession or occupation, any stratum of society, any walk of life. It is not necessarily a bad trait; in fact, it can probably be credited with many of the scientific and technical discoveries throughout history. But while trained incapacity may sharpen focus, it must also limit it. Thus, counterbalance is necessary. This can come in the form of sensible and sensitive skepticism that inquires into the content of the "boxes on the blackboard" and questions not only the slope of carefully-contrived curves but what they mean, that scrutinizes the modes of thought and methods that supply conclusions and solutions. It is conceivable that thoughtful review undertaken in this fashion will lead to better questions and better answers.

<u>Fatalistic Faith in Science and Technology</u>

Resigned reliance on science and technology manifests itself in the kind of logic seen in the following sequence: mankind is caught in an inexorable course from which there is no escape. Science is the only salvation. Perhaps science will kill us; perhaps it will save us. The more complex and awesome the proportions of the problem the more likely is this kind of fatalistic resignation to occur. Nor, one may note, is it born of ignorance. With respect to issues as complex as those surrounding energy, the thinking person is likely to be more deeply concerned than his complacent neighbor. He probably listens to more discussion, puzzles over the conflicting "facts," and senses the gravity of taking or not taking certain courses of action. Psychologists tell us that under circumstances of this kind, because the mind is burdened by a welter of stimuli, a phenomenon called "sensory overload" can occur. One of its manifestations

[22] Thomas J. Connolly, "Implications of the California Nuclear Power Plan Initiative," Presentation before the California State Assembly Committee on Energy and Diminishing Materials, Sacramento, Calif., December 2, 1975, pp. 8-10.

is irrelevant or inappropriate response. Perhaps this explains the reason why otherwise intelligent people will say of radioactive waste, "Let them go dump it in an ocean somewhere," or, of radiological hazard, "We all have to die anyway; this is just another way of making it happen." This type of serio-comic logic probably underlies public acceptance of the notion that all forms of energy are potentially dangerous. "You can burn your finger on a match," was an argument put forward by a lobbyist against California's initiative to curb nuclear power development. Implicit here is a kind of fatalistic faith in science that would fit well into P. A. Sorokin's concept of "Epicureanism of despair." That this attitude reflects resignation and may even be flippant must be recognized, for it can deflect intelligent discourse and defeat the most earnest efforts at eliciting public participation.

Implications of the Credibility Issue

Recognition of the gravity and complexity of problems generated by and associated with nuclear energy has caused ever-growing dependence on the advice of specialists and experts. And, following Parkinsonian principles, the ranks of experts have swelled to meet the need. But this has only compounded the problem, for how do we assign expertness? By degrees earned? Years of experience? Salary? Position? Criteria for quality elude measurement; attempts have deteriorated into numbers games. One such effort quantified academic acumen by scrutinizing lists of publications and counting references to a given individual's work in the literature in his field. How, why, by whom, and for what purpose the citations were made were not specified. Completely ignored in the earnest arithmetic exercise was the possibility that the author and his works had been singled out for devastating criticism as a horrible example! Quality evaluation eludes measurement and, as a consequence, attribution of expertness and the accompanying factor of credibility remain largely personal and often an intuitive matter. We ascribe credibility through a number of reference points in our own value system, itself a creation of our life history in its own cultural milieu and as affected by the socialization processes which have occurred. Sociological theory, as developed by Mead,[23] tells us that each of us has his own "significant others," or "influentials," and that these affect our acts and attitudes.

When, therefore, we review the areas of contention vis-a-vis the disposition of radioactive wastes and recognize the extent to which opinion polarizes the positions taken, we realize that credibility is a basic issue. This quality, like truth and beauty, resides in the eye of the observer. And, whatever the position we choose to espouse, we will find good authority ranged on our side. With Noble Laureates in drastic opposition one to another, the question, then, is which one do you believe? Despite this basic dilemma, invoking "expert" advice and opinion is prescribed practice in public and private administration. The fact that implicit in the process is a choosing up of sides is generally overlooked. Consequently, the issue of credibility is treated as though it did not exist, whereas, on the contrary, it is fundamental.

Reliance on experts entails an interesting domino movement. Some experts expound confidently on the process by which energy is generated through fission and then relegate the problem of safeguards and disposition of wastes to some other realm of expertness. For example, Bethe[24] reviews the energy situation at home and abroad, now and in the future, recommends nuclear fission as "the only major nonfossil power source the U.S. can rely on for the rest of this century and probably for some time afterward," and then discusses the disposal of the wastes. He details the steps in handling the spent fuel, his exclusive emphasis and faith relegated to the technical aspects.

> It is difficult to see how any of the radioactive material could get out into the environment after such treatment, provided that the material is adequately cooled to prevent melting.[25]

Thus assuming the technical perfection of a system and sidestepping and "sweeping under the rug" the myriad of unresolved nontechnical and, in the final analysis, most troublesome problems associated with disposal,[26] Bethe ponders storage repository and recommends permanent storage deep underground, bedded salt being his preferred medium.

> First, the existence of a salt bed indicates that no water has penetrated the region for a long time; otherwise the salt would have been dissolved. Water trickling through the storage site should be avoided, lest it leach the deposited wastes and bring them back up to the ground, an extremely slow process at best but still better avoided altogether. Second, salt beds represent geologically

[23] George Herbert Mead, Mind, Self, and Society, Chicago, Univ. of Chicago Press, 1934.
[24] H. A. Bethe, "The Necessity of Fission Power," Scientific American, January, 1976, pp. 21-31.
[25] Ibid., p. 27.
[26] "Nuclear Foes Fault Scientific American's Editorial Judgment in Publishing a Recent Article by Nobel Laureate Hans Bethe," Science, 26 March 1976, pp. 1248-9.

> very quiet regions, -they have generally been undisturbed for many millions of years, which is good assurance that they will also remain undisturbed for as long as is required. Third, salt flows plastically under pressure, so that any cracks that may be formed by mechanical or thermal stress will automatically close again.

He dismisses the Lyons, Kansas debacle with the comment that it was "unfortunately undertaken in a hurry without enough research." Thus an eminent scientist takes a strong position about the necessity of nuclear power--an essentially economic and social matter--and then delegates the urgent problem of waste management to an area of expertness that is not his own.

How, then, does the geologist view burial in salt mines? William W. Hambleton, Director of the Kansas Geological Survey and a member of the Kansas Nuclear Energy Council,[27] refutes the "hurry without enough research" claim made by Bethe by recounting the years of research that have gone into radioactive waste storage, salt formations having attracted the attention of a National Academy of Sciences committee as long ago as 1955. Actual studies began at Oak Ridge in 1959 and investigation of sites in Kansas were initiated in 1963. Thus, Bethe's allegation that the Lyons disposal was "undertaken in a hurry without enough research" is unfounded.

Hambleton has traced the painstaking steps through which the AEC chose the abandoned Carey Salt mine at Lyons. Project Salt Vault utilized spent fuel assemblies, along with electrical heaters, to simulate the possible environment within an actual repository. The mine was equipped with instrumentation to record temperature, radiation, and physical properties of the salt. Ascertained were the seismic stability of the area, the large area of salt with the overlay of 800 feet of rock and the "hospitality of the people of Lyons." Despite the confidence born of precautions, the Lyons site turned out to contain a number of unidentified wells. Moreover, during a hydraulic mining operation, the American Salt Company had injected fresh water only to have some 180,000 gallons disappear. In Hambleton's words, "No one can discover where the water went. In other words, the Lyons site is a bit like a piece of Swiss cheese, and the possibility for entrance and circulation of fluids is great." He recommended that it be abandoned forthwith: "There is nothing more important than recognizing a dead horse early and burying it with as little ceremony as possible."[28]

With respect to salt-mine storage in general, Hambleton and his fellow geologists have some reservations. They challenge as overly simplified the two-layer, two-dimensional heat-flow model used by the AEC in its calculations. They question the rock mechanical model used for studies of mine subsidence as inadequate to accommodate the temperature dependence of some rock and the de-watering of shales as well. They believe that calculations fail to take into account the possible energy storage insult through radiation damage and the subsequent release of energy as a thermal excursion, with respect both to the salt and to the radioactive waste itself. Nonetheless, Hambleton indicates that the Asse Radioactive Waste Repository in Germany may ultimately provide some answers, because "competent scientists are in charge of the programs, which appear to be free of irrational political influence."[29] (Emphasis added) Note the way in which the specialist in geology imputes competence to his colleagues and implies faith in the process but also exhibits his biases. He seems to suggest that "political influence" can be a disturbing factor and, moreover, that political influence is "irrational." This position is not entirely consistent with accounts of the Lyons, Kansas experience, where the aroused public brought to bear "political influence" that time and subsequent investigation by the AEC proved to be far from irrational.

In somewhat similar fashion, technical experts are wont to assign responsibility elsewhere. The Safeguards Program of the Liquid Metal Fast Breeder Reactor Program is a case in point, its waste management problems already presumably solved by projected attainment of a "geologic disposal facility."[30] Reference is made to programs "underway to develop [a geologic disposal pilot] plant for demonstrating safe geologic disposal by 1983, well in advance of requirements for the LMFBR Program, to meet the requirements associated with the LWR fuel cycle and the wastes resulting from the production of nuclear weapons." The problem of waste management is then relegated to the year 1999 or later, with confident expectations for no serious constraint on the LMFBR program "imposed by disposal requirements for high-level or transuranium wastes."[31]

[27] William W. Hambleton, "The Unsolved Problem of Nuclear Wastes", Technology Review, March/April, 1972, pp. 15-19.

[28] Ibid., p. 18.

[29] Op. cit., p. 19.

[30] U.S. Energy Research & Development Administration, Liquid Metal Fast Breeder Reactor Program, Final Environmental Statement, December, 1975, Vol.I, p. S-7.

[31] Ibid., p. S-8

A phenomenon which can be called an intellectual passing-of-the-buck is widespread in the matter of radioactive waste handling. Not only has there been evidence of relying on technologies not yet devised but also of relegating the problem to others' spheres of responsibility. Witness, for example, the nuclear engineer who responds to direct questions about the risks by saying, "That is the non-technical part of the process. If Congress will supply enough funds, we can carry out certain technical and developmental activities. What we need is public acceptability." To the technically minded, getting public approval is recognized as important, but the process by which this is to be achieved turns out to be one not of creditable performance in waste management but rather of convincing the public through smart tactics that its concerns are groundless! Thus, we find plans for public opinion surveys, media campaigns, and other manipulative tactics to persuade the Nervous Nellies that risk-taking is an old American custom, that radiological exposure may be benign; in short, that there need be no concern about wastes. To some engineers, technical matters pose few problems. Left out of their formula are two vital ingredients: (a) technology is not self implementing; (b) technology is not self-evaluating.

The proclivity to dump the waste management problem into someone else's baliwick has occasionally relegated it to the realm of the industrial psychologist. The personnel problems associated with monitoring and surveillance have been identified as so crucial as to warrant special efforts at creating esprit de corps and elevating morale among workers. In view of the relatively glamorless "garbage man" image associated with wastes, the task, if valid, is of no mean proportions. As numerous studies in industrial relations have shown, employee loyalty and morale are highly complex matters and less amenable to manipulation than is sometimes naively thought. In fact, the spurious sociality of the use of the first name, the slap on the back, and the annual "family outing" of the organization have been known to boomerang, with suspicion rather than cordiality the result.[32]

When the dominoes tilt, they ultimately fall into the domain of the social and political. The problem of the disposition of radioactive wastes is, it is generally conceded in the final analysis, a social problem. Interesting to note, this interpretation of the matter throws it into the area of public affairs and, as in the case of the California Initiative, calls for "public participation." But since there is agreement that the problems associated with nuclear energy are complex and beyond the grasp of most citizens, it is necessary to invoke expert opinion. And so the circularity of the process becomes evident and the credibility gap, which we have discussed in the preceding section, becomes a credibility trap.

Throughout this paper, we have stressed the issue of credibility. It should be clear by now that veracity does not lie on one side alone and mendacity automatically on the other. Wisdom does not predominate in either position. There are, as we have seen, foolish arguments among the pro's and among the con's. But while the temptation to throw the decision to the public at large is great, this may not yield satisfactory results either, because the same old parade of experts is called upon to perform. As we have indicated earlier, public participation has been viewed as an opportunity for various kinds of intervention; it has been construed as a propaganda play to manipulate opinion. It has been seen[33] as "a crucible for many of the problems of political science" and not as a solution for them. One study[34] finds that public participation is not so much an effort to broaden the base of democracy, as a means to "'cool out' potential opposition by co-optation, and thus preempt the possibility of a more vigorous challenge to policies and programs at a later stage of implementation." The proposition has been put forward[35] that the concept of citizen participation has been fostered by government bodies to legitimate pre-ordained courses of action and thus deflect criticism at some later time.

Recognition of the pitfalls and of the possibilities for misuse need not, however, deter the Nuclear Regulatory Commission from pursuing its objective to elicit and encourage public participation in matters related to the management of radioactive wastes. Once we have acknowledged that the problem has dimensions far exceeding those which have been defined as technical, then we are in better position to raise and seek answers to a broad range of questions. Here, the understanding and bona fide participation of the public are essential lest decisions, engineered under conditions of "monopolization of knowledge,"[36] hasten the demise of the very democratic system we desire to preserve through enlightened energy policies.

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32 Ida R. Hoos, Automation in the Office, Washington, D.C., Public Affairs Press, 1961.

33 B. Whitaker, "Participation and Poverty," Fabian Research Series 272, 1968.

34 John Bennington and Paul Skelton, "Public Participation in Decision-Making by Governments," Government and Program Budgeting: Seven Papers with Commentaries, London, The Institute of Municipal Treasurers and Accountants, 1973.

35 E. A. Krause, "Functions of a Bureaucratic Ideology: Citizen Participation," Social Problems, 1968, p. 129.

36 S. M. Miller, "Policy and Science," Journal of Social Policy, January, 1974, p. 56.

ASSESSMENT OF METHODOLOGIES FOR RADIOACTIVE WASTE MANAGEMENT

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ASSESSMENT OF METHODOLOGIES FOR RADIOACTIVE WASTE MANAGEMENT

Historical Background

Because of the almost total reliance on quantitative techniques to compare, evaluate, and proceed on all aspects of nuclear energy generation, it is important to scrutinize critically the methods in use. Whenever methodology comes under critical review, the argumentum ad hominem generally advanced is that the tools are above reproach and only their application is faulty. This technocratic type of response obscures the issue. Obviously, we do not concern ourselves with an evaluation of tools on the shelf nor with methods in the abstract. And yet, we do not deem it entirely irrelevant to assess what they are, since, by definition, both carry the implication of application. Webster's International lists a tool as "a simple mechanism or implement, as a hammer, chisel, plane, spade, or file, used in working, moving, or transforming material." Similarly, a method is "a general or established way or order of doing or proceeding in anything." To separate the tool from its use or the method from its application may, therefore, be a pedantic ploy. We prefer to address the methodology of management science in terms of the ways the tools and methods are used, whether they are appropriate to the tasks, and how they affect decision-making processes.

Since many of the techniques have been in use for some years, there is a considerable history upon which we may draw for insights.[1] Some of them have undergone mutation and appear with refinements in new guises, like risk-benefit assessment. But the principles remain basically unchanged. Best known are the techniques of cost-benefit and cost-effectiveness analysis. (Although the terms are often used practically interchangeably, there is a distinction, residing in the units by which effects are quantified.) A widely accepted description of cost-benefit analysis, supplied in a seminal statement by Prest and Turvey,[2] better expresses the ideal to be attained than the reality as observed during the past decade of experience.

> A practical way of assessing the desirability of projects, where it is important to take a long view (in the sense of looking at repercussions in the ...future) and a wide view (in the sense of allowing for side-effects of many kinds on many persons, industries, regions, etc.), i.e., it implies the enumeration and evaluation of all the relevant costs and benefits. (Emphasis added.)

The cost-effectiveness approach is implicit in studies directed to the management of radioactive wastes. Some, which we will discuss later, were designed to assay the relative merits of various disposal sites--sea, salt mines, or space. It is probably due to the application of cost-benefit calculations that the waste management end of the nuclear fuel cycle has until recently been accorded such low priority. With outlook for profit limited and with an image devoid of honor (cf. the "garbage man" notion), the management of waste received far less serious attention than was subsequently officially recognized. Even in arriving at basic choices as between possible sources of energy--nuclear, geothermal, solar, and the like--cost-benefit analyses have been routinely applied. This practice is consistent with accepted government policy, it being virtually mandatory that figures on costs and benefits be supplied as justification for almost any official course of action, be it in energy, transportation, health, education, or welfare.

It may be noted that there is nothing inherently new or magical about these methods. A child trying to decide whether to spend his dime on a miniature fudge bar or a longer-lived package of gum performs a cost-benefit analysis and makes a trade-off. A housewife applies the principles, even if only intuitively, to her grocery shopping. Managers have always used them in the running of their affairs. The only aspect that is at all new is the name of the game. And what is remarkable is the way in which the old concepts underlying cost-benefit ratios, now

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[1] Ida R. Hoos, Systems Analysis in Public Policy, Berkeley, California, University of California Press, 1972 p. 42.

[2] A. R. Prest and R. Turvey, "Cost-Benefit Analysis: A Survey," The Economic Journal, December 1965, p. 683.

given a name, are greeted with such acclaim and accorded so much authority. In this phenomenon, we are witnessing a repeat performance of Molier's play, "Le Bourgeois Gentilhomme," in which an uneducated tradesman, bent on acquiring instant culture, hires a tutor and learns with delight that what he has been talking all his life is prose!

In the annals of the United States government, the concept dates back to the Flood Act of 1936, when Congress declared that costs of Federal projects should not exceed benefits. The notion was newly accredited during World War II when it emerged in the context of weapons system atization and selection by Rand analysts. It was this epoch in the development of the family of quantitative techniques encompassing systems analysis, cost-benefit analysis, and program budgeting that assured their longevity, since their adoption, refinement, and application by then Secretary of Defense Robert S. McNamara and Assistant Secretary Charles J. Hitch rendered them the core methodology of management science. By the 1970's, a new chapter in the history of the methodology began. The same principles prevailed but new applications brought new labels, predominant among them, risk-benefit analysis. Cohen, for example, suggests this methodology as a guideline for the calculation of low-dose radiation to populations,[3] the objective being as follows:

> to determine a rational, definitive, and generally acceptable means of evaluating the potential benefits of any given operation, program, or technology against the possible risks.[4]

If to this indisputably praiseworthy purpose is added the injunction by the General Accounting Office[3] that "all pertinent beneficial and adverse effects" be taken into account, we find ourselves with the Prest-Turvey recipe paraphrased, updated, but no closer to realization. Despite their high sound, the words have a hollow ring. This can be appreciated when we scrutinize the key concepts.

In the context of the methodology, "rational" and "definitive" mean a quantitative, preferably economic, measure, even in cases where data are controversial, conjectural, and highly questionable, not suitable for quantified treatment, and probably more doctored than firm. Moreover, economic rationality might dictate a policy which would be at variance with political rationality, and both could be at serious odds with social rationality. "Rationality," then, reflecting the analyst's value judgment, contains a basic contradiction: tools purported to be "scientific" are really subjective. Not only are there many conceptions of rationality, but they can lead to severely conflicting objectives.

"Evaluating" is used in the limited, mathematical sense of "finding a numerical expression." Adherence to these principles makes for a perpetual internal contradiction which precludes the possibility of accommodating Prest and Turvey's inclusion of "all the relevant costs and benefits," or the GAO's "all pertinent beneficial and adverse effects." In almost any public decision, be it dam, transportation, or military budgeting, dollar costs and benefits, calculated as they must be for a short period or assigned some arbitrary discount rate over time, cannot and do not encompass all the costs and benefits, nor all the beneficial and adverse effects. To begin with, no one is endowed with omniscience sufficient to recognize them as they exist in the present, let alone to conjecture with any degree of reliability what they will be in the future. Moreover, by virtue of its very purpose, viz. to obtain a numerical ratio, the technique forces selective data gathering and utilization as well as arbitrary assignment of values (hence the "evaluating"), in both of which quantities are unknown and not appropriate. The cost-benefit exercise systematically neglects a large class of factors that, while eluding quantification, might count most heavily in outcomes. It tolerates fooling with figures to substantiate certain objectives and, at the same time, allows for cavalier dismissal of the incalculables. Bearing in mind that the cost criterion does not define the only valid measure, we can then entertain the likely possibility that a solution that may appear less than optimal in relation to a certain goal may nonetheless be preferable in real life terms and in the long run. One might even venture the proposition that the more precise the cost-benefit ratio, the more likely it is to be wrong, if not now, then eventually.

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[3]Jerry J. Cohen, "A Suggested Guideline for Low-Dose Radiation Exposure to Populations Based on Benefit-Risk Analysis," Livermore California, University of California Lawrence Radiation Laboratory, June 1971.

[4]Ibid., p. 5.

[5]U.S. General Accounting Office, "Improvements Needed in Making Benefit-Cost Analyses for Federal Water Resources Projects," Report to the Congress by the Comptroller General of the United States, B-167941, Washington, D.C., September 20, 1974, p. i.

Even after thirty years of experience in applying cost-benefit methods, water resources agencies, for example, have not succeeded in overcoming such basic weaknesses as costs underestimated, with calculations confined to visible dollar amounts, opportunity costs omitted, spillovers overlooked, and a range of present and future social costs ignored.[6] On the benefit side computations have been over-optimistic, not adequately supported, and lacking in consistency. Nor will these pitfalls be readily overcome, since they stem from inherent shortcomings of the techniques. Nonetheless, the methodology is in wide use and much public money is wasted on performing cost-benefit analyses and on the projects they "rationalized." They have buttressed decision-making processes in which artificial segmentation (under the guise of "suboptimization") has been encouraged. They have provided a format useful for justifying ends conceived narrowly in space and time so as to achieve yields which may have appeared high but which ultimately defeated larger and longer-lived objectives. The result has been a false sense of security in decisions or courses of action because they were arrived at "rationally" or "scientifically." Actually, in almost every branch of government, examples of mismanagement are on the increase and can be attributed in large measure to reliance on these tools of management science. Cost-benefit analysis and related techniques have not demonstrated that they have improved public decision-making but merely that they have provided a convenient rationale for just about any course of action; it all depends on who wants to justify what.

The standard technocratic response to this kind of criticism is either a retreat to the drawing boards for technical adjustment of the model, almost irrespective of the real-life vagaries, or a resort to the offensive: these tools must be used because we lack better ones. Implied here is the dilemma of the wrong cure. Should we continue to rely on and base policy on techniques even though they are demonstrably inadequate and inappropriate? The documented experience of the U.S. Army Corps of Engineers, for example, reveals that many decisions, made on the basis of this kind of logic, have turned out to have undesirable, unanticipated, and regrettably irreversible effects. Instead of perpetuating the mythology of the methodology, perhaps we need to reconceptualize public management problems so as to embrace the full spectrum of their dimensions. When, for example, the problem is imbedded in a web of social, economic, political, and environmental strands, we need to recognize the dangers of distortion by definition, which fashions the problem to fit the tool.

Cost-Benefit Concepts as Applied to Nuclear Decisions

Not surprisingly, in view of current public management practice, cost-benefit concepts have been applied to decisions regarding nuclear energy. Some have focused on the trade-offs between nuclear and other sources of energy; some have addressed the "back end" of the fuel cycle; some have moved from benefit-risk into the more future-oriented mode of risk-analysis. In the first category, cost-benefit calculations have been said, in current bureaucratic jargon, to have "illuminated" choices, but this illumination resembles the well-known drunkard's search![7] As a method for calculating trade-offs as between nuclear and other energy sources, cost-benefit exercises continue to be very popular. Their main pillar of strength is information, but we soon learn that data on supply, costs, and benefits can be selected and interpreted to "prove" almost any point. They depend on the predilection and orientation of the analyst. Anticipating impacts of alternative energy options is a guessing game, with Peter paid and Paul robbed to fit a set of equations. The models rest on a foundation of assumptions, which often reflect bias and even wishful thinking.

A popular ploy is to concentrate on a few known (although not necessarily universally-accepted) figures and to extrapolate from them projections that make the future look bright for a favored option. Thus, by focusing on air pollution, one study[8] had certain models appear to stress a range of advantages of nuclear over coal or oil power, since the latter are both calculated, for higher growth rates in electricity consumption, to cause emissions that will exceed air quality standards. Specified as costs in the latter instances are increased construction and operating expense occasioned by better control equipment, as well as the disadvantages imposed on society if air quality standards were to be relaxed. While the original study, labelled "Impacts of Alternative Electricity Supply Systems for California,"[9] was fairly careful in its

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[7] A. Kaplan, The Conduct of Inquiry, Chandler, San Francisco, Calif., 1964, p. 51, tells the story of a drunkard, hunting under a lamp post for keys dropped some distance away. When asked why he does not look where he lost them, he replies, "Here is where I can see."

[8] William E. Siri, Jayant A. Sathaye, Leonard Kumin, et al., Impacts of Alternative Electricity Supply Systems for California, Lakewood, Colorado, Western Interstate Nuclear Board, May 7,

[9] Ibid.

caveats, the Executive Summary, titled "Regional Effects of California Nuclear Moratorium,"[10] was necessarily eclectic and revealed strong bias. Even so, we are told that although airborne radioactive emissions eventually disappear in the coal and oil cases, they will increase by ten times in the nuclear case for the high rate of growth. On "impairment of economic values embodied in nuclear plant and facilities," both Report[11] and Summary are specific, both citing the rate increases and other burdens placed on taxpayers and consumers to reimburse the California utility companies for capital losses. By contrast, there is less concern for the effects of radioactive emissions from power plants in 1990. They "appear to be well within the levels permitted by current Federal regulations, assuming normal dispersion in air and water."[12] This statement is unduly optimistic. To state that present regulations, which are controversial today, will prevail and can be met in 1990 is unfounded. To assume "normal" dispersion in air and water may be quixotic. Not taken into account is the fact that "normal" dispersion will take place in an environment already far from pristine. Not only are there already known instances of "migrations" of radioactivity that are far from normal and, therefore, elusive of capture in a neat formula, but there are predictions of an increase in the flux of ultraviolet radiation due to reduction in the stratospheric concentration of ozone.[13] "Normal dispersion" must be calculated in terms of a spectrum of events and circumstances. That "management and ultimate disposal" of radioactive wastes is mentioned only in passing indicates how arbitrary, indeed, is the process of assigning the full costs of nuclear energy, other studies having indicated that, depending on regulations, the back end of the nuclear fuel cycle could render it uneconomical.

In an era of contract research, brains for hire, the intellectual counterpart of the condottieri of old, carry out cost-benefit studies to fill any bill. Obedient consultants in think tanks and accommodating academics of all stripe constitute a reservoir of talent for this purpose. They produce "data" to substantiate any position. They dutifully interpret "facts." As a result, several sets of experts can use the same body of information and reach totally different conclusions. What is more remarkable, the same group of researchers, using the very same data that they themselves had gathered in a study for FEA, could come up with three different Executive Summaries![14]

Charles Warren, Chairman of the California State Assembly Committee on Resources, Land Use, and Energy, describes[15] how this came about:

> When the first completed version of the draft report arrived about a month ago, the executive summary was seemingly done in haste, lacking in some detail and quality, but all in all, a brief, fair summary of the results. About ten days later, a second executive summary arrived. This document was systematically and rather grossly biased emphasizing results favorable to the defeat of the Initiative, stating results not found in the main body of the report, and virtually ignoring important results favorable to passage of the Initiative. A bitter debate at the last Oversight Committee meeting resulted in a third executive summary. It is certainly better than the second; the obvious bias has been removed. However, in my opinion, it still does not accurately represent the spirit of the results of the study.

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[10] Western Interstate Nuclear Board, "Regional Effects of a California Nuclear Moratorium, A Summary of Impacts of Alternative Electricity Supply Systems for California," Lakewood, Colorado, WINB, May 1976.

[11] Op. cit., p. 55ff.

[12] Executive Summary, op. cit.

[13] Committee to Study the Long-Term Worldwide Effects of Multiple Nuclear-Weapons Detonations, Assembly of Mathematical and Physical Sciences, National Research Council, Long-Term Worldwide Effects of Multiple Nuclear-Weapons Detonations, Washington, D.C. National Academy of Sciences, 1975, see especially pp. 90-96.

[14] Federal Energy Administration, Direct and Indirect Economic, Social, and Environmental Impacts of the Passage of the California Nuclear Power Plants Initiative, Executive Summary, V. I, Joint Report of Five of the Eight Members of the Oversight Committee, April 1976.

[15] California State Assembly Committee on Resources, Land Use, and Energy, "Impacts of the California Nuclear Power Plants Initiative," Vol. XVI, May 14, 1976, p. 2.

Review of the FEA-funded study by Professor Kai Lee, Chairman of the Oversight Committee,[16] underscores the wisdom of the old adage, "Whose bread I eat, his song I sing." To this, we can add the observation that no matter how earnest or honest the efforts to apply cost-benefit analyses to energy options, bias is inevitable and often so deeply imbedded as to elude dection. To claim, then, that this methodology yields answere that are definitive" is merely a subjective judgment bestowed by those who approve the outcome.

When applied to possible courses of action with respect to the disposition of high-level radioactive wastes, cost-benefit analyses have not been particularly illuminating. This is due to several insurmountable difficulties: (1) the dearth of reliable information forces limited conceptualization and, consequently, the drunkard's search;[17] and (2) by virtue of its quantitative nature, the methodology either excludes many of the crucial desiderata or distorts them by inclusion. Subtle acknowledgement of these shortcomings may be deduced from the way in which Battelle expanded its long term study of radioactive waste management. The earlier effort[18] provided cost estimates for the various concepts under consideration. However, too many crucial facets were in the realm of conjecture to allow for any kind of reliable comparisons. The second, considerably expanded study,[19] eschews such calculations and concentrates on a description of technical alternatives for managing wastes from the back end of the commercial LWR fuel cycle. While avoiding many of the pitfalls of the conventional cost-benefit approach, the voluminous report nonetheless conveys a number of dubious impressions. By its arbitrary "shooting of the arrow and drawing the target," it neatly avoids most of the troublesome issues. Cheerful but unsubstantiated assumptions establish "feasibility" across a range of options as though they were equally possible, safe, and reliable. Thus, technical competence is implied, even in the face of known failure or total lack of experience. There have been leaks at Hanford; performance at Maxey Flats, Kentucky, has been less than satisfactory;[20] there has been radioactive contamination of the ocean; we have not yet tried outer space; and there are doubts about the ice sheets. Schematic drawings notwithstanding,[21] the space trip is conjectural, and even were the "true final disposal," i.e., impact with the sun, the chosen option, serious questions have been raised as to which would happen first: a burnup by the intense solar heat or a pickup by the powerful solar winds!

Because only the technological aspects are addressed, social, economic, political, and environmental desiderata are bypassed as not relevant to the study. But this reduces it to a meaningless exercise in simulation, since none of the waste management options would be taken in a social vacuum. Moreover, as Marcus A. Rowden, Chairman of the U.S. Nuclear Regulatory Commission, pointed out,[22] the safe management of radioactive wastes calls not only for a trustworthy technology but also for a process for the timely implementation of that technology. To proceed with tunnel technological vision would be to trivialize and distort the problem of radioactive waste management. Ultimately, this could undermine the efforts and effectiveness of the Nuclear Regulatory Commission. The paramount danger in relying on cost-benefit type analyses for radioactive waste management decisions is that the determining factor cannot be how much it costs but how safe it must be and what must be done to assure that safety. Here, the NRC has a mission of the utmost importance, one that has been brought into sharp focus by a ruling (July 21, 1976) of the U.S. Court of Appeals for the District of Columbia that calls for explicit attention to the range of environmental dangers in the handling of radioactive wastes and the reprocessing of spent fuel.

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[16] Ibid., p. 57.

[17] Cf., A. Kaplan, op. cit.

[18] K. J. Schneider and A. M. Platt, Eds., Advanced Waste Management Studies, High-Level Radioactive Waste Disposal Alternatives, U.S. AEC Report BNWL-1900, Battelle, Pacific Northwest Laboratory, Richland, Washington, May 1974, as summarized in High-Level Radioactive Waste Management Alternatives, U.S. Atomic Energy Commission, WASH-1297, May 1974.

[19] Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel Cycle, ERDA-76-43, Report coordinated by Battelle, Pacific Northwest Laboratories, at the request of the Division of Nuclear Fuel Cycle and Production, U.S. Energy Research and Development Administration, 5 Volumes, May 1976.

[20] Comptroller General of the United States, Improvements Needed in the Land Disposal of Radioactive Wastes--A Problem of Centuries, Government Accounting Office Report B-164105, January 12, 1976, pp. 14-15.

[21] See, for example, Figure 26.3 Re-entry Shield and Transuranic Disposal Package for Solar Escape Destination, Vol. 4, p. 26.5.

[22] Marcus A. Rowden, Statement before the Joint Committee on Atomic Energy on the Subject of Nuclear Waste Management, May 12, 1976 p. 5.

Risk Analysis as Applied to Nuclear Decisions

Like cost-benefit analysis, the methodology utilized in risk-assessment is an extension of the family of systems analysis techniques developed by the Department of Defense and the National Aeronautics and Space Administration. It is, in large part, vulnerable to the same criticisms.[23] Even in the Department of Defense, where the concepts were spawned, we see no convincing evidence that Rand-style management corrected flagrant wastefulness, bad planning, and dubious strategy. In fact, some of the more glaring instances of such failings have been attributed to use of these very techniques. The transplant of Rand procedures to all types of public problems and the movement of Rand experts from coast to coast, from Southern California to New York City and Washington, have not contributed perceptibly to more "rational" tools, use of which will lead to better decisions. Nonetheless, the notion, now our "dominant paradigm,"[24] is pervasive.

Because we tend to conceive of problems in terms of the methodology, the models we develop are perforce limited; they are mere restatements in symbolic language of the premises and assumptions. Once having established this definition, we then proceed by logical inference and various calculations to conclusions which, although often taken as gospel, are sheer tautology. Time and again it has been demonstrated that another set of assumptions, different data or a different weighting of variables would yield a different result. Therefore, the more we depend on mathematical models for our assessments and predictions, the greater is the need for scrupulous analysis and critical review, instead of the contrary tendency to accept the results without question. It has been pointed out that with respect to reactors, assumptions regarding the reliability of predictions derived from computational codes may well be one of the weakest aspects in nuclear reactor safety.[25]

The Reactor Safety Study, often referred to as WASH-1400, or the Rasmussen Report, had as its prime purpose the assessment of "risks to the public from potential accidents in nuclear power plants of the type being built in the United States today."[26] In order to achieve its task, the study team developed a probabilistic "fault-tree" analysis of potential failures in the reactor system. As described by Yellin,[27] this was an ambitious attempt "to construct a complete, stochastic model capable of predicting the absolute probabilities of occurrence of all human and component failure sequences which contribute significantly to potential reactor accidents." Since the procedures of event-tree and fault-tree analysis have been proposed for radioactive waste management, it might be useful to review some of the more salient criticisms, before, as has occurred in the case of the parent methodology, systems analysis, the emperor's new clothes obscure our view.

It may be noted, as a point of philosophical reference, that underlying fault-tree analysis is the Bayesian theorem, otherwise known as the "equiprobability of the unknown criterion," which states that where there is no information available about relative probabilities, we must assign equal probabilities in our calculations and then adopt a particular strategy. This makes the Bayesian analyst a subjectivist, for he is concerned with degrees of belief. He estimates probability distributions although it is not clear in advance which unknown possibilities are to be considered equally probable. It has been argued[28] that unless we have some advance information on the number of categories into which the alternatives should be classified, the Bayes equiprobability-of-the-unknown approach can leave the relevant probability figure completely ambiguous. Thus, the impression of certitude conveyed by the "systematic" progression through the "logic diagram" may be an illusion.

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[23]Marcus A. Rowden, Statement before the Joint Committee on Atomic Energy on the Subject of Nuclear Waste Management, May 12, 1976, p. 5.

[24]This is T. S. Kuhn's concept, defined as a fundamental way of perceiving, thinking, and doing, consistent with a particular view of reality. It functions as the disciplinary matrix of beliefs, models, and values. T. S. Kuhn, The Structure of Scientific Revolutions, Chicago, University of Chicago Press, 1971.

[25]Keith Miller, (Professor, Mathematics Department, University of California, Berkeley; Consultant, Advanced Code Review Group), "Recommendation Relating to the Licensing of Commercial Nuclear Power Plants in the USA," Memorandum to the Commissioners, U.S. Nuclear Regulatory Commission, May 6, 1976, p. 2.

[26]U.S. Nuclear Regulatory Commission, Reactor Safety Study, An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants, (NUREG 75/014), WASH-1400, October 1975, p. 3.

[27]Joel Yellin, "The Nuclear Regulatory Commission's Reactor Safety Study," The Bell Journal of Economics, Spring 1976, p. 327.

[28]William J. Baumol, Economic Theory and Operations Analysis, Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 1961, pp. 372-373.

The process of making decisions under conditions of uncertainty has been analyzed in a seminal study by two psychologists.[29] Their thesis is that people rely on a limited number of heuristic principles which reduce the complex tasks of assessing probabilities and predicting values to simpler judgmental operations. The research reveals that these heuristics, while psychologically useful, can lead to severe and systematic errors. A number of examples strengthen their contention that probability assessment is an inherently subjective process and that from the standpoint of the underlying formal theory, <u>any</u> set of internally consistent probability judgments is as acceptable as <u>any other</u>.

We discern this pattern in fault-tree/event-tree application, where a range of probabilities is defined, and where areas of concern may be systematically excluded. This was the crux of much of the criticism levelled at the draft version (August 1975) of the Reactor Safety Study.[30] The methodology was challenged there and subsequently for its inadequacy, the contention being that event-tree and fault-tree analysis could not produce reliable quantitative predictions of systems failure probability. Some reviews have concentrated on the weaknesses of the overall approach--Kendall and Moglewer,[31] for example, pointing to failures in aerospace and ballistic programs. Yellin[32] not only raised serious issues about the method of analysis but also pointed out specific discrepancies and ambiguities that render the Study less suitable as a document upon which to evaluate the probable social costs of nuclear power (a) than might have been anticipated by the Atomic Energy Commission and (b) than might be implied from the battering ram use to which the results have been put. Further critical analysis of the Reactor Safety Study is to be found in the Report to the American Physical Society by the study group on light water reactor safety.[33] The study, conducted more to "help inform the scientific and technical community about some of the technical issues of reactor safety"[34] than to evaluate Draft WASH-1400, pointed out some of the deficiencies of the methodology, especially those relating to present calculations of absolute values of the probabilities of the various branches of the fault-tree.

Kendall[35] and other critics point out the impossibility of developing a mathematical model which would identify all the possible malfunctions that can occur and the ways in which specific failures within the system relate to each other. In the absence of such a model, the analyst's simulation prevails and this is perforce a reflection of his particular perception of the problem <u>and not necessarily the most accurate or reliable one</u>. In the words of Professor Keith Miller, whose research specialty is the design and analysis of numerical methods by which complex mathematical and scientific problems can be approximately solved by computers:[36]

> One tends to forget that one's computerized collective vision of reality, calibrated only against model tests at small scale, could be very, very far off from actual, full-scale reality, <u>and yet</u> we would never know it.

Since its initial appearance, the Reactor Safety Study has undergone considerable revision and recalculation. But the basic methodology is unchanged. And, in fact, not only has iteration of the arguments supporting the approach cloaked it in an aura of credibility but the necessity to defend their conclusions on many occasions in high places and before the public has developed a remarkable degree of forensic sophistication on the part of Professor Rasmussen, his NRC staff, and their expert consultants.[37] So inexorable has been the logic of their defense of the event-tree/ fault-tree that they are inclined to deflect, by definition, criticism of <u>both</u> the method and their calculations. These critical remarks notwithstanding, it can be pointed out that the Reactor Safety Study stimulated discussion of important issues, exposed data and

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[29] Amos Twersky and Daniel Kahneman, "Judgment Under Uncertainty: Heuristics and Biases," <u>Science</u>, 27 September 1974, pp. 1124-31.

[30] U.S. Nuclear Regulatory Commission, Reactor Safety Study, (NUREG 75/14) <u>op. cit.</u>, Appendix XI, p. XI 3-1.

[31] Henry Kendall and Sidney Moglewer, "Preliminary Review of the AEC Reactor Safety Study," San Francisco and Cambridge, Sierra Club and Union of Concerned Scientists, November, 1974, p. 113.

[32] <u>Op. cit.</u>, p. 329.

[33] Report to the APS by the study group on light-water reactor safety, <u>Reviews of Modern Physics</u>, Vol. 47, Supplement No. 1, Summer 1975.

[34] <u>Ibid.</u>, p. S.4.

[35] Henry Kendall and Sidney Moglewer, <u>op. cit.</u>, pp. 113-114.

[36] Keith Miller, Memorandum to the Commissioners, May 6, 1976, <u>op. cit.</u>, p. 2.

[37] See Hearings, U.S. House of Representatives, Subcommittee on Energy and the Environment, Committee on Interior and Insular Affairs, June 11, 1976.

methods to scrutiny, and increased the understanding of light-water reactors and of their potential hazards. However, while the more sophisticated technical analysts dealing with the Study and its conclusions have recognized its limitations and made no extravagant claims for the predictive process of the methods used, others have found the conclusions extremely useful. Thus, in front of television cameras and for the press, proponents of nuclear energy have cited the Study's calculated risks as substantiation for minimizing hazards to the point of likening them to a meteorite mishap. The heights of hyperbole, and at the same time a reduction to total absurdity, when the Study's results are cited as basis are such statements as the following:[38]

> If the[se] risks are spread evenly among all U.S. inhabitants, the risk to the individual is equivalent to driving in an automobile for an extra 10 or 15 minutes each year.

Because of the basic simplicity of the methods and the official imprimatur for them, we find many persons varying widely as to both discipline and capability performing risk analysis as well as other types of cost-benefit analyses. While, as we stated earlier, the tools per se are not an issue, their applications are. Properly, the output of an analysis should be given only with a clear indication of the larger uncertainties surrounding the results, these being due to (a) the uncertainties in the basic input data utilized; (b) uncertainties inherent in the modeling process; and (c) uncertainty as to the appropriateness of the data and its pertinence to the problem being addressed. Moreover, imperative and often lacking is an articulation of the parameters on which the system is being judged. Rarely if ever does one find a candid statement that the list is probably incomplete because we do not have full information, knowledge, or understanding. And more frequently than not, quantitative techniques cannot accommodate the information, knowledge, and understanding that we have. In view of the gravity of the myriad of decisions relating to energy, it is important that we recognize the limitations of the techniques and avoid the illusions of certainty created by their application.

The point that the eclectic nature of the techniques focuses attention on certain problems and systematically neglects others deserves attention because of the extent to which fault-tree and related techniques are being ubiquitously applied and accepted in many situations where a state of uncertainty prevails. What this means with respect to nuclear energy is that persons seeking less stringent regulations of certain phases of the fuel cycle could, by astute utilization of this method, understate the hazards calling for safeguards. This would ultimately serve to impugn the NRC and undermine its credibility. Its necessary regulatory functions would be criticized for imposing needless and costly safeguards. If, on the other hand, an incident were to occur, the NRC would be blamed for not having protected the public. The "logic" thus applied could seriously undercut the NRC's ongoing efforts[39] at safe disposal of radioactive wastes.

Carrying the technique to another area of great concern, one might appropriately raise the question as to where the methodology would lead if applied to the mammoth uncertainties associated with experimentation and research on recombinant DNA and the efficacy of biological containment. By performing his calculations, the technical virtuoso provides the quantified comfort that all relevant contingencies have been included and the ex post facto retrospective assurance that none of the known near-catastrophes could, statistically, have occurred! The lesson that remains to be learned, however, is that the simulated security may serve as a siren song lulling us into neglecting other areas of legitimate concern.

While it is not our intent nor within the province of this paper to catalogue perilous omissions and their consequences, we nonetheless deem it necessary to draw attention to several based on assumptions unsupported by experience. It is important that we do this because rational decisions cannot depend on analyses, no matter how logical internally, that fail to meet the pragmatic test of reality. If, as is so often claimed, these techniques "illuminate choices," they do so only after the fashion of the lantern shining in the night--by making the dark darker. By dint of the nice bit of sophistry that rules out the "what if" question as not meaningful

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[38]Thomas J. Connolly, "Nuclear Technology and the California Nuclear Initiative," Chapter Three in The California Nuclear Initiative: Analysis and Discussion of the Issues, Stanford, California, Institute for Energy Studies, 1976, p. 92.

[39]W. P. Bishop, "Radioactive Wastes: Disposal Alternatives," paper presented at "Energy in Perspective: An Orientation Conference for Educators," Arizona State University, June 7-11, 1976.

because "it does not fall within the accident sequences defined in the event-tree,"[40] the methodology forecloses mention of omissions and shortcomings worthy of attention. Our observations of the "popular" interpretation of the Study's conclusions indicate the possibility of a boomerang effect: if the Study's risk calculations were to be given too great credence, the inevitable feedback would be an emasculation of the Nuclear Regulatory Commission's vital functions. With so little to fear from even the worst eventuality, why, might we ask, is there all the pother about security at every step, safeguards in every phase, and tumult about terrorism, sabotage, and the like? Perhaps these are after all a figment of the imagination of the Nervous Nellies and whistle-blowers, bent on destroying U.S. industry and the American economy.[41]

The way in which the Study's conclusions are used is to present us with the statistically contrived certainty that (a) no serious nuclear incident will occur and (b) the radioactivity released need be of little concern. Further, necromantic manipulation of data conveys the notion that nuclear power is safe compared to coal with its mining disasters, particulate emissions, and radioactive smokestacks, less harmful than diagnostic X-rays to which one submits without hesitation, and must less risky than than travel by air or car, or the myriad of "normal" activities associated with living in today's world.

The Regulatory Function

But regulatory agencies do not function in a never-never land of stochastic models where all systems go with methodical precision and the unthinkable can be calculated not to happen. There is no reason to believe and good reason to doubt that the concerns of American citizens will be allayed by methodological virtuosity. The statistical confidence game, no matter how clever, is not designed to inspire public confidence. It was played with respect to Vietnam, with obvious results. The legacy of distrust in government and the response of civil disobedience from that past era may, in fact, have significant impact on the future history of nuclear energy.

As evidence of rampant public distrust of government, surveys[42] have uncovered widespread lack of confidence in the government's capability, intent, or will to serve the citizenry effectively. A New York Times/CBS News national poll[43] revealed that alienation has reached epidemic proportions, some millions of persons having rated the government as incompetent, inefficient, and unworthy of their confidence and trust. Arthur H. Miller,[44] reporting on information gathered by the University of Michigan Survey Research Center, notes a sharp drop in public trust over the past six years. His observation on this phenomenon and its implications is portentous.

> A democratic political system cannot survive for long without the support of a majority of its citizens. When such support wanes, underlying discontent is the necessary result, and the potential for revolutionary alteration of the political and social system is enhanced.

The NRC, as the country's newest regulatory body, does not yet have a crystallized image. It can, therefore, participate in creating its own and in this process it has several options. The Commission can emulate other, older organizations and perform the tired tricks which have contributed to public distrust. It can proceed in such fashion as to be vulnerable to charges of conflict of interest; it can make the mistake of serving the interest of a special industry rather than that of the public. It can tread the path of its parent, the AEC, and thus defeat one of the basic purposes for which Congress established it. Use of methodological magic will only minimize the enormity of its task; resort to public relations ploys to belittle the detrimental effects of radiation will only deprive the Commission of its full range of authority. Instead of allowing its importance to be undervalued and its impact undercut, the NRC must help

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[40] Testimony of Mr. Saul Levine, (Deputy Director, Office of Nuclear Regulatory Research, USNRC), before the Subcommittee on Energy and the Environment, House Committee on Interior and Insular Affairs, June 11, 1976, p. 11.

[41] Remarks of Congressman Mike McCormack, as quoted in Gail Sheeby, "California's Impossible Nuclear Decision: A Reporter's Personal Search for an Answer," New West, June 7, 1976, pp. 57-58.

[42] See, for example Ada W. Fanifer, "Dimensions of Public Alienation," American Political Science Review, June, 1970.

[43] James T. Wooten, "Ocer Half of Polled Feel Distrustful of Government," The New York Times, February 24, 1976.

[44] Arthur H. Miller, "Political Issues and Trust in Government: 1964-1970." The American Political Science Review, September, 1974, p. 951.

educate the public to the fullest possible understanding of the whole range of costs and benefits associated with nuclear energy.

This is a worthwhile objective and one not at all alien to U.S. regulatory agencies. Turning back the pages of history to an earlier chapter, one finds that the philosophy underlying the establishment of such agencies can be drawn on to strengthen this purpose. Forty years ago, a Congressional committee investigating telephone companies recognized that where protection of the interests of the public was concerned, a "coherent and constructive program of regulation" was a sine qua non. Specific details for implementation as spelled out in the following paragraph, are remarkably pertinent to the nuclear case today:[45]

> It is fundamental that the administrative process must be so developed as to fill the need of the occasion for expertness. In the highly technical field of telephone rate and service regulation this fact is of peculiar import. Only if it be fortified with an adequate staff, continuously employed solely in the exploration of these problems, can any agency hope to develop the sound, positive, and effective regulatory methods which are requisite. Indeed, it has become obvious that the experience, expertness, and continuity of management attained by the American telephone industry must be matched to the highest practicable degree by equivalent experience, expertness, and continuity of supervision of the part of the representatives of the public, if the regulatory process is to become even measurably successful in this technical and highly specialized field of interstate public administration. This means that a staff of adequately trained experts must be developed with specific responsibility in connection with wire-communications problems ... (Emphasis added)

The Real-World Context of Nuclear Safety and Security

Functioning as it must in the real world, the NRC has many areas of legitimate concern, not all of them calculable nor acknowledged in the simulated world of the risk analyst. The NRC will get more credit for attending to these problems than for trying to convince the public that they do not exist. There must be recognition, first and foremost, of the present no-man's land lying between elegant design and successful implementation, between careful drawing and actual execution. It is at this rarely explored interface that some of the NRC's major responsibilities lie. Can anyone seriously contemplating nuclear safety fail to comprehend the import of 3,055 "problem welds" on the Alaska oil pipeline and the way they have been "corrected"[46] with falsified, missing, or suspect radiographs?

Regulation is not, by and large, a glamorous occupation. It is, in practice, often reduced to a perfunctory exercise, with inspection a ritual performance. Through persistent underrating of the function in government personnel classifications, official agencies have not been able to attract as high a level of expertness as the private industries requiring regulation. Thus, a heightened susceptibility to "snow jobs," where the contrary is urgently needed. The rescue of regulatory activity from ignominy could be accomplished by recruitment of a staff of first-rate technical personnel and explicit articulation, instead of calculated avoidance, of hazards. A well-known fact of occupational life[47]--one that is corroborated by industrial relations research --is that mistakes, whether deliberate or intentional, are bound to occur. Although they are inevitable, their incidence and consequences cannot be anticipated,[48] let alone adequately represented in a risk analysis model. Corroborated by experience, if not quantification, is the fact that inspection and maintenance procedures are likely to be relaxed if no major reactor accidents take place; thus, the probabilities for such occurrences are enhanced.[49] Risk analyses, based on past events, would perforce lead to contrary conclusions.

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[45]Committee on Interstate and Foreign Commerce, 76th Congress, 1st Session, Investigation of the Telephone Industry in the United States, A Report of the Federal Communications Commission on the Investigation of the Telephone Industry of the United States, as Unanimously Adopted by the Commission, June 14, 1939.

[46]Edward Cowan, "Bad Welds Found in Alaska Oil Line," The New York Times, May 22, 1976. James B. Sterba, "Pipeline Faults in Alaska Persist," The New York Times, June 13, 1976.

[47]Jeffrey W. Riemer, "Mistakes at Work--The Social Organization of Error in Building Construction Work," Social Problems, February, 1976, pp. 254-268.

[48]IEEE Spectrum, "What Went Wrong?," Special Issue, October, 1976.

[49]Op. cit., Report to the APS by the Study Group on Light-Water Reactor Safety, p. 526.

Conventionally, a logical way to circumvent mistakes, especially those due to human misbehavior or miscalculation, has been to automate. Such has been the intent at the Halden Reactor Project, [50] where emphasis has been directed to advanced computer-based methods for plant and reactor core control, for safety and protection, and for overall supervision of nuclear power stations. In load control, and in control of coolant flow and level, increased automatic control has been seen as necessary and the human operator ruled out.[51] State-of-the-art appraisal indicates, however, that some key problems remain to be solved.

Despite the defensibility of the theory of total automation, there is no unanimity among nuclear scientists as to the wisdom of relying on digital computers in reactor protection and control systems. Epler and Oakes cite a lack of criteria for such applications.[52] Raudenbush[53] cites standards to insure redundance, reliability, and separation of power-reactor instrumentation (IEEE Standards 279 and 308) but draws on research to support the contention that the operator-automation interface has been neglected. He concludes as follows:[54]

> The most significant general problem areas noted in present control-system layout design appear to derive from lack of knowledge of human engineering principles among nuclear plant designers. Even such advanced control boards as the Robinson have some controls that are difficult to operate, gauges that are hard to read, and confusing alarm arrangements, all indicating a need for injection of human engineering expertise into nuclear control-board design.

Raudenbush's recommendations are consistent with those of the American Physical Society:[55]

> Human engineering of reactor controls, which might significantly reduce the chance of operator errors, should be improved. We also encourage the automation of more control functions and increased operator training with simulators, especially in accident simulation mode.

No matter how well designed the automated system nor how sophisticated the human engineering aspects, glitches[56] are bound to occur. The range of systemic pitfalls, errors in instrumentation, vagaries of functioning, and programming problems, well known to nuclear engineers, is of such magnitude that slighting any of them is to do serious disservice to efforts to anticipate and overcome them, especially insofar as they are tractable to technical treatment. In a world where cost-benefit practices prevail, such efforts will be given short shrift, however, unless it can be convincingly shown that they are, indeed, vital. Not only with respect to the safe operation of reactors but also in reprocessing plants, the possibilities for malfunction are great, probably far greater than is made to seem in risk calculations, which are based entirely on inadequate, if not faulty, data. While some scenarios step up to a number of critical issues, the full import is never encompassed. Problems relating to all phases of the nuclear fuel cycle are addressed as though they were nothing more than a highly complicated technical matter, that by astute calculation, can somehow be resolved. This is cavalier in the extreme, for the methodologies in current use contrive an aura of security but systematically neglect the social environment in which exploitation of the nuclear option occurs. The point that needs to be made and iterated is that regulation cannot be construed as merely a technical matter; it is a social responsibility and must be performed in a socially responsible manner.

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[50] Organization for Economic Cooperation and Development, Nuclear Energy Agency, Fifteenth Annual Report, Halden Reactor Project 1974, Paris, 1975.

[51] Ibid., p. 32

[52] Ibid., p. 103.

[53] Michael H. Raudenbush, "Human Engineering Factors in Control-Board Design for nuclear Power Plants," Nuclear Safety, January-February 1973, p. 21.

[54] Ibid., p. 25.

[55] Op. cit. (Report to the American Physical Society by the Study Group on Light-Water Reactor Safety) p. 57.

[56] "Glitches" are shoptalk for errors that, once located and understood, seem more glaring and blatant than "bugs." This is the definition offered by J. C. R. Licklider, "Underestimates and Overexpectation," in ABM, An Evaluation of the Decision to Deploy an Antiballistic Missile System, eds. Abraham Chayes and Jerome B. Weisner, New York, Harper & Row Publishers, Inc., 1969, p. 125.

Every phase of nuclear energy development, from the mining of the raw material to the disposal of its wastes, entails an almost unprecedented combination of technical issues, all of which contain high social content, and a new order of responsibility. Besides the systemic pitfalls, nightmarishly familiar to nuclear physicists and engineers, computer scientists, and software specialists, there is another range of concerns, less tangible, but nonetheless real. This resides in the social environment and results from the unpredictable synergy of technology, times, events, and circumstances that have made America vulnerable to all kinds of attack, from subtle sabotage to outright terrorism, and have rendered nuclear materials a handy vehicle for both.

The stark fact is that our highly advanced technological society is seriously vulnerable to guerrilla attack, which is manifested in myriad ways. One of them has to do with the relative ease with which widespread disruption could be caused by interference with computerized control systems. The "threat models" devised by "tiger teams," for example, demonstrate that there is no foolproof design. Penetration depends ultimately on the sophistication and intent of the malefactor.[57] Underlying many of the instances of malfeasance now part of the public record, from Watergate on, has been the prevailing philosophy that the end justifies the means. Thus, acts of burglary, blackmail, and falsification have all been rationalized as contributing to a worthy end. Similarly, a zealot bent on serving the cause of humanity in his own ideological terms, could try to trigger the big catastrophe that would abort the nuclear effort. If, as is conceivable, such a person were strategically situated, he could, through his knowledge and manipulation of the system, do considerable harm. The element in a system most likely to cause its disruption is often obvious and open to sabotage. It is well known that the entropy factor in the life-cycle of complex systems often manifests itself first as an aberration that can later be deliberately induced to cause trouble; he more than anyone else could put that knowledge to the work of destruction.

Why, one might ask, would anyone commit sabotage? There are many reasons: ideological, political, economic, psychological, and sociological. Even the innocuous "Peter Principle" has been suggested as a factor contributing to employee frustration that might seek strange outlets for expression. Manifestations of employee disgruntlement can take many forms, as is suggested in the following news items selected at random. While none of these points to acts of self-immolation nor spells of nuclear disaster, taken in conjunction with certain attitudes, events, and opportunities, they could nonetheless lead to grave consequences.

- Des Moines Sunday Register, March 14, 1976 "Four Suspended: Refuse to Work in Nuclear Plant"
- The New York Times, April 27, 1976, "Hearing on Plutonium Plants is Told of a Conflict over Health Reports"
- The New York Times, May 4, 1976, "Strike Idles World's Only Dual Reactor"
- The Daily Californian (Berkeley), "Navy Atom-Fuel Plants: Safety Questions; Low Pay"

To understand the full synergistic import of these items, one need only consider the following:

- The New York Times, March 30, 1976, "U.S. Proposes to Fine Utility for not Keeping Unstable Ex-Employee out of Nuclear Plant"
- The New York Times, April 6, 1976, "G.A.O. Says Employees of Breeder Reactor Corporation Would not be Subject to Laws"
- The New York Times, May 11, 1976, "G.A.O. Finds Security is Lax in U.S. Computer Installations"

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[57]See, for example, Robert P. Abbott, Liena M. Boone, et al., A Bibliography on Computer Operating System Security, Livermore, University of California, Lawrence Livermore Laboratory, prepared for AEC, April 15, 1974.

Donn B. Parker, "Manual for Investigation of Computer-Related Incidents of Intentionally Caused Losses, Injuries, and Damage," Livermore, University of California, Lawrence Laboratory, prepared for AEC, February 1973.

Ministry of Defence, The Secretariat for National Security Policy and Long-Range Defence Planning, The Vulnerable Computer Society, Stockholm, Sweden, 1976.

Not only is the possibility of vendetta from within likely, but opportunities abound. If we take a page from lessons learned in the banking industry, where there is heavy reliance on computers, we find that preservation of system integrity is a matter of growing concern. Not only is there evidence that current precautionary measures have failed but there is also the suspicion that only the tip of the iceberg of abuses is known.[58] Financial losses are already being calculated in the millions of dollars. Where the items at risk are not only money but also public health and safety, there is added to the dollar cost of protection the range of social costs, not the least of which are those relating to infringement of civil liberties. While present system safeguards, considered fairly adequate for the current fuel cycle,[59] are not seen as a threat in this respect, the prospects change drastically when plutonium recycling comes into focus. Cited as a case in point in a legally-oriented review,[60] is the Kerr-McGee nuclear fuel processing plant in Cimarron, Oklahoma, where workers were required to submit to lie detector tests in order to qualify for employment and where those who refused were demoted or transferred to menial jobs. Among the questions put to them were whether they had ever talked to newspaper reporters, whether they belonged to the union, whether they had ever been involved in "anti-nuclear activities," and whether they had ever had an affair with another plant employee.

Discussing problems relating to employee security, the Harvard Civil Liberties group[61] directed attention to the 1974 amendment to the Atomic Energy Act of 1974, under which the Nuclear Regulatory Commission is em-powered not only to investigate the "character, associations, and loyalty" of workers but to establish "standards and specifications that will deter-mine who may and who may not be employed." The question was raised as to how far-reaching was the government's power to acquire information about a prospective employee so as to decide whether to hire him or about an incum-bent employee as to his retention. They pointed out that the courts had already shown concern with the effects of such investigations on the indi-vidual's freedom of speech and association, right to be free from unreason-able search and seizure, and right to privacy. The problem was outlined as follows:[62]

> The most serious civil rights problems for nuclear industries employees will concern their due process rights not to be denied employment or fired for constitutionally impermissible reasons. Two kinds of cases may arise: first, where the asserted grounds for dismissal are themselves unconstitutional, for example, where the employee is a member of a dissident group; second, where the asserted grounds for dismissal are themselves proper but where the actual motive for the dismissal is an attempt to stifle dissent.

Regarded[63] as the ultimate question for the courts to decide is whether the dangers of plutonium are so overwhelming as to warrant restriction of the civil rights of workers in the interests of national security. The dilemma is many-pronged. There must be good reason for vigilance. Otherwise, what the NRC considers to be necessary protective measures could appear to be little more than paranoiac panic; the NRC could even be accused of assuming a pseudo-CIA stance. <u>Unless</u> infringement of civil liberties is justified, present personnel practices and proposed investigating measures could actually give impetus to a potential surge of civil disobedience that could take forms which would incur further repression. Such occurrences, not uncommon but usually unforeseen, have the feedback effect of propelling themselves into "movements."[64] On the other hand, if the full gamut of safeguards is, indeed, necessary, then we must reckon with the total range of social costs involved. That they are intangible and incalculable in no way diminshes their importance or detracts from their implications. The NRC cannot afford to ignore them. In fact, its very credibility and longevity may depend on how well its calculations and policies reflect them.

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[58] Donn B. Parker, <u>Crime by Computer</u>, New York, Charles Scribner's Sons, 1976.

[59] <u>U.S. General Accounting Office, Improvements Needed in the Program for the Protection of Special Nuclear Material</u>, Washington, D.C., B-164105, November 7, 1973.

[60] "Policing Plutonium: The Civil Liberties Fallout," <u>Civil Liberties Law Review</u>, <u>Harvard Civil Liberties</u>, Spring, 1975, pp. 387ff.

[61] <u>Ibid.</u>, pp. 387 ff.

[62] <u>Op. cit.</u>, Harvard Civil Liberties, p. 397.

[63] <u>Ibid.</u>, p. 399.

[64] Hannah Arendt, <u>Crisis of the Republic</u>, New York, Harcourt Brace Jovanovich Inc., 1972, see esp. "Civil Disobedience," pp. 51-102.

Perhaps nowhere is the phenomenon of synergy more apparent and dramatic than in the ways technology and the tenor of the times interact to impose new challenges. Transportation and communications technologies have virtually eliminated distance, with the result that Uganda is as close as one's television set and Tokyo can be reached before breakfast. Political unrest in the Middle East is immediately translatable to bomb blasts in consulates in Pacific Heights, San Francisco. Nationalistic "liberation" movements are pandemic; their potent weapons for exerting pressure on world opinion have high visibility. Stakes are concentrated and high, and terrorists always play to a world-wide audience. Thus, terrorism is a very effective means of accomplishing certain purposes. Attention is often directed via satellite to the cause it serves; a small band of determined desperadoes can blackmail a whole country. New York City might not fall to invaders from Outer Slobovia, or wherever The Mouse that Roared had its origin, but this is not to say that technology and terrorism could not combine to cause serious disruption to some of the great cities and vital nerve centers of the country.

One need only specify as one of the facets in the synergy that of widespread computerization to sense a dimension of danger hitherto neglected in discussion of nuclear safety. A study recently performed under the aegis of the Swedish Ministry of Defence[65] outlines in telling detail the areas in which a computerized society becomes more and more vulnerable to attack. Anticipating dynamic expansion in computer technology, the research group concerns itself with some of the developments and their likely consequences. The tenor of their report and many of the observations can be usefully pondered in this context. When transferred to the American scene, they contribute an important element to the synergistic process which we have been discussing. Especially relevant are such matters as the concentrations of various kinds of information that follow in the wake of computerization. Experience from the Second World War confirms the assumption that a possible aggressor would find such centers (a) especially useful and (b) fairly easily disrupted. In case of the latter, EDP-dependent activities, which are numerous and increasing, would be curtailed. Thus, all kinds of communication as well as interaction and cooperation between different parts of society would be interrupted.

Since such events are likely to take place only under conditions of social stress and unrest, perhaps even war, the study group emphasized the need for keeping the vital functions in the society as intact as possible. Reliance on the computer seemed to constitute an "Achilles' heel."[66] Seen as a possible source of risk from the vulnerability point of view is the build-up of networks of computers, in that destruction of one central computer could make several systems useless. Dependence of computer operation on assured power sources was suggested as a problem. In this respect, one need only refer to the APS light-water reactor safety study[67] to learn that an extended loss of off-site power could result in many control functions being lost. In case of failure of both the off-site electric power system and its backup, emergency power for the plant is provided by auxiliary diesel generators, recognized as a weak point in the system. The record shows[68] that not only do about three percent of them fail to start when asked, but also that some, once properly started, trip when required to assume full emergency load. If an extended loss of off-site power were to occur, through sabotage, terrorism, hostile attack, or other untoward circumstance, and if the diesel backup were to behave recalcitrantly, the results could be dire, if not disastrous.

Conclusion

The Reactor Safety Study notwithstanding, no quantitative methodology is adequate to encompass and assess all the risks, no risk/benefit calculaton is fine-tuned enough to supply decision-makers with the full range and all of the dimensions. Quality assurance, stressed in the APS Report,[69] cannot be conceived in terms of systems design alone, but must be maintained vigilantly and with integrity throughout the process. The responsibility of the NRC is fairly well established with respect to overall reactor safety. With respect to the management of radioactive wastes, its mission is not yet so clearly delineated. Herein lies a challenge and an opportunity. Where the known quantitative methodologies are restrictive and likely to have negative feedback effect on authority and public support, the broader lens and the bolder thrust are called for. The cozy cocoon of figures ultimately protects no one. The Commission, having acknowledged that the management of radioactive wastes is not merely a technological matter can now take the socially responsibile position of exploring as fully and confronting as

[65]Ministry of Defence, The Vulnerable Computer Society, op. cit.

[66]Ibid., p. 6.

[67]Op. cit., pp. S27-28.

[68]APS Report, op. cit., pp. 27-28.

[69]Op. cit., pp. S28-29.

candidly as possible the total range of dimensions involved. Paradoxically, it is Charles J. Hitch, intellectual progenitor of the methodology, who observes[70] that we may be missing the meaning of his message by relying too heavily on quantitative analysis and thus defining our task too narrowly. In an article on energy, Dr. Hitch, now president of Resources for the Future, reminds us that we live in a closed system, in which science and technology, politics and economics, and, above all, social and human elements interact, sometimes to create the problems, sometimes to articulate the questions, and sometimes to find viable solutions.

[70]Charles J. Hitch, "Harnessing the Inexhaustible Sun," The New York Times, June 20, 1976.

REMARKS ON MANAGERIAL ERRORS AND PUBLIC PARTICIPATION

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REMARKS ON MANAGERIAL ERRORS AND PUBLIC PARTICIPATION

There seems to be a general failure by persons writing on radioactive waste management to differentiate between the technologist whose primary concern is the technology itself and the project manager who selects those bits and pieces of the technology that he believes will enable him to achieve his projects' operational goals while still satisfying the array of non-technological constraints to which it is subject such as budgets, time schedules, environmental impacts, required operational lifetime of project facilities, project dollar economics, etc. This fuzziness in role then extends to confusion between the basic tehchnology and the relative success or failure of the project utilizing selected elements of it. As a result of this vagueness, any project failure or lack of performance becomes proof of an inadequate technology although such failure or deficiency was in fact due to managerial decisions on how to use the available technology and still satisfy the overriding non-technological constraints.

For example, the Lyons, Kansas Salt Mine Project, as we understand the facts was set up originally by technologists as a technological field experiment to verify that the behavior of encapsulated high-level radioactive wastes in a salt mine environment would be as technologically predicted. For this purpose the site selected was well chosen. At a later date a managerial decision was made to use the site as an official permanent operating depository for wastes. For this purpose the site was not adequate (as local authorities were able to show) so that instead of the project resulting in a much needed demonstration experiment it ended in a fiasco. This was purely a managerial error. It does emphasize the point that the results of a technological enterprise are sensitively dependent on the effectiveness with which management uses available technology. It says nothing, however, about the adequacy or inadequacy of waste management technology. To use it, as is being done widely, as proof of the inadequacy of the involved technology is utter nonsense.

The case of the leaks in the Hanford waste storage tanks is another totally distorted cause celebre. To call this a failure of waste management technology is to confuse the issue. Operational mismanagement did occur, but that event proved out the validity of the technological decisions made approximately twenty years earlier. Before the storage tanks were built, the character of the underlying soil was studied in detail. Its ion-exchange, adsorption properties were examined thoroughly. The indications were that wastes spilled on that soil would be strongly adsorbed in distances well short of any existing water table. The leaks when they came demonstrated the validity of those early studies. With this knowledge the technological specifications for the tanks were prepared. They were to provide economical, essentially trouble-free operation for a postwar period of sufficient duration for a permanent waste management system to be developed and installed. If my memory of the discussions is correct, this was assumed to require a lifetime of some twenty years. The full extent of stress corrosion was not anticipated, but even if it had been the lack of field annealing facilities at that time would have made correction of the stress corrosion disease impossible. As it was, adequate safety margins were designed in and the system met the specs. Far from a "technological fix" or "technological failure" the Hanford tank farm has been a technological success. Even the management failure would appear to have been as much a result of the contracting administration's approach to the Hanford operations as it was the operating manager's laxity in carrying out the waste tank inspection routine. Examination of the parallel waste management program at Savannah River reveals a steadily improving storage tank technology and a thoroughly under-control management system. Contrary to widespread propaganda and consequent public belief, the liquid storage facet of the high-level waste management system has proven to more than satisfy the original design requirements and thus provides a proven technological base for future industrial use. That this part of the system can be operated reliably over the necessary extended periods of time has been fully demonstrated by the Savannah River Operation.

A similar clarity of distinction needs to be established between administrative and managerial decision-making. In the former specific policy objectives are enacted which all operational decisions must support and rigid procedures for arriving at those decisions are established. Given a set of input data, the content of the resulting decision is largely foreordained and its applicability to the case in question fully justifiable. Its effectiveness in dealing with the situation of concern depends on the adequacy and reliability of the input data and upon the validity of the policy goals.

In the case of the managerial decision, although broad policy goals may be recognized, the setting of immediate operational goals frequently becomes an essential part of the decision-making process. Equally often the input data that would be necessary for a fully objective analysis of the proposed operating situation simply are not available. Since time is almost always of the essence in operational situations, managerial decisions frequently must be made on the basis of managerial judgment. This in turn depends upon the manager's prior experience in similar operating circumstances and upon the counsel he obtains from his staff and consultants. How effective a managerial decision will be depends, therefore, not only upon the manager's analytical skill and the reliability and adequacy of the available data, but also upon the extent and applicability of his past experience and upon that of his advisors.

In any discussion of governmental operations and in particular in those involving regulatory functions, it is imperative that this distinction between the administrative and managerial decision-making processes be meticulously observed.

The next subject is the very basic question of, "Who is the public?"

The leaders of industry, of big business, of activist conservation groups, of organizations of dedicated environmentalists, of militant consumerist associations, etc., all have one thing in common, they all possess a fanatical belief that they and they alone are the true servant of the body politic and thus the sole justified agent to represent it in any matter that, as they see it, impinges in some fashion on "the national welfare." The truth is, of course, that each does indeed represent one significant fragment of the total societal complex which, as an integrated complex, determines the material quality, the intellectual character and the spiritual vitality of the nations's "standard of living." Each needs to present its area of concern for public scrutiny and action. No element of the complex, however, can exist within the framework of present societal structure without the others. Thus no particular fraction within the complex can claim the title, "the concerned public." If there is a matter of serious public concern, the total citizenry, whether aware of the matter or not, is in fact concerned and not simply that segment of it which gives highly vocal expression to its awareness. And when made fully and accurately aware of this matter that concerns their welfare there is no certainty that the total citizenry will reach the same assessment of the problems involved and of the actions to be taken as that at which the "concerned public" group arrived.

What this says is that despite any claims to special concern for the public welfare, no segment of the public should be permitted to exercise greater political pressure than any other on any determination of what is in "the public good" or, conversely, be required to exert any less. That segment of the society with the most experience and greatest expertise in the area of concern must be relied upon to provide the factual foundation requisite for an objective assessment, to outline the lines of action available for implementation and to present the probable consequences of each as its impact filters out through the entire operational fabric of the societal system. That done, its priority role ends; it merges back into its accepted place in the structure of the public as a whole. Then it is the total public that, starting from this factual matrix of options and consequences, must carry out the necessary multifactoral cost benefit evaluations and make the final operational decisions.

Clearly the total public is a creature with a multitude of personalities. No single line of action can be equally "good" for all. How to arrive at an operationally effective decision becomes a matter of crucial societal importance.

As the information explosion continues unabated, the time honored mode of rule by majority vote of the electorate is no longer tenable. A "town meeting" decision was sound and effective because the problems to be resolved were mostly concerned with matters of common experience and those voting were all adequately skilled in dealing with them. As a result, the decision reached was based on well known fact and was the product of well tested judgment.

It is no longer possible to duplicate this process. The vast and exponentially increasing fund of basic knowledge which must be recognized in arriving at any sound decision means that even the exceptionally literate voter rarely commands the requisite data base for valid decision-making in more than a very minor fashion, the complexity of our societal structure with its maze of interdependencies has compelled a degree of individual specialization that strictly limits the range of affairs within which that individual's judgment is reliably competent. Under these circumstances, a societal decision-making mechanism that places the responsibility for final determination of the course of action directly upon the electorate means that the data base for the finding shifts from fact to opinion and the assessment function regresses from experimental judgment to hunch, emotional attitude or magic. Since opinion can be manipulated readily and since hunch, emotional attitude and all forms of magic are the antithesis of logical analysis, this direct populist mode of decision-making, while it may serve the current "public will," serves the "best public interest" only by chance if at all and utlimately leads to sure disaster.

Whether accomplished indirectly through the subterfuge of equivocal populist initiatives or directly through skilled manipulation of legal process, rule by small but potent activist minorities will inevitably debilitate present governmental strengths, eventually accomplish their own demise and ultimately lead to cultural decadence or armed insurrection. And this despite largely laudable goals and acknowledgedly good intent. It must be noted, however, that all Hell is divided into three parts, that paved with good intentions, that paved with the perversions of good deeds and that paved with high, but fallacious ideals.

If the "concerned citizen" groups do not represent the total body politic and if chance dominates that total body's direct attempts to represent itself, the question arises, "Who does represent the public?" As long as the U.S. Constitution remains unmodified and in force, the answer is clear. As far as the public interest in all matters pertaining to the societal use of nuclear energy and its associated technology is concerned, when appointed by the President and confirmed by the U.S. Senate, the Commissioners of the Nuclear Regulatory Commission become the personification of the public for all operational purposes. It is their responsibility not to serve the current "public will" but to use the full powers of the Government and the vast resources available to it to determine what indeed is the "best interest" of the public and then to see that that interest is effectively served. To be pragmatic about the matter, however, a primary operation of the Commission in achieving "effective service" of its finding with respect to "the public's best interest" will always be the difficult educational task of bringing "the public understanding" and "the public will" into consonance with the facts of its findings. This is essential. It is admittedly difficult, demanding and expensive. To avoid this responsibility, however, by bringing Commission actions into consonance with a finding of current public opinion would be commit misfeasance and drive one more nail in the coffin of effective representative government.

OBSERVATIONS AND IMPRESSIONS ON THE NATURE OF RADIOACTIVE WASTE MANAGEMENT PROBLEMS

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OBSERVATIONS AND IMPRESSIONS ON THE NATURE OF RADIOACTIVE WASTE MANAGEMENT PROBLEMS

1. Introduction

In the course of our deliberations on the goals of radioactive waste management, the Task Group collected observations and impressions on the nature of radioactive waste management problems. We organized these observations and impressions into five basic categories. These are:

- Perceptions of the waste management problem;
- Hazards of radioactive wastes;
- Methodology for assessment of radioactive waste management;
- Decision processes in waste management;
- Problems of implementation of a waste management system.

We make no pretense about the completeness of the observations and impressions reported herein.[1] They do not represent a consensus, or even the majority opinions of various groups nor do we endorse these views as our own. They are simply significant themes collected during the course of our deliberations. Many are merely common-sense statements which we felt worthy of articulation. Many are in a state of change and will be relevant only briefly.

In reviewing them as we assembled this paper we were struck by the fact that most of the observations take the form of admonitions to the Federal decision makers.

2. Perceptions of the Waste Management Problem

AMONG THE ISSUES REGARDING NUCLEAR POWER, WASTE MANAGEMENT MAY BE PIVOTAL, AND IS CERTAINLY ONE OF THE MOST IMPORTANT AND URGENT.

While some data indicate that the radioactive waste issue may not be the most important in terms of threat to human well being, it is clearly thought of as a major problem. The environmental, political, and regulatory communities assess it as being more serious--for political reasons--than does the business community which views it primarily in technological terms. Extremes are presented by environmentalists and others who are sure that radioactive wastes cannot be disposed of safely and those nuclear scientist and engineers who are sure that they can be.

RADIOACTIVE WASTES DO NOT RANK AS HIGHLY (AS A PROBLEM) AS OVERPOPULATION, ECONOMIC CONDITIONS, AND OTHER SIMILAR CONCERNS.

Outside the arena in which the nuclear issue is debated, the problem of radioactive wastes is not viewed as particularly important. However, the legacy of the wastes is one of the impacts on future generations which seems to be most apparent as arising from mankind's present activities.

NO ONE WANTS RADIOACTIVE WASTES IN HIS BACKYARD.

Lacking economic incentives only nuclear technologists seem prepared to accept wastes disposed in their immediate neighborhood. However, the psychic trauma of living with the wastes could be the single greatest burden on the local populace.

THE GOVERNMENT MUST BE RESPONSIBLE FOR RADIOACTIVE WASTE MANAGEMENT.

Most seem to feel that beyond the first few years (during which the industry will handle the wastes) the government should be responsible. Some of the statements which lead to this conclusion are:

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[1] Others have attempted more thorough and broad analysis. See for instance, Proceedings of Conference on Public Policy issues in Nuclear Waste Management, October 27-29, 1976, Chicago Nuclear Power and the Public: Analysis of Collected Survey Research, PNL-2430, Battelle Human Affairs Research Centers, Seattle, November 1977.

- Government is responsible for the health, safety, and welfare of the public;
- Private industry cannot be, and cannot be required to be, perennially responsible;
- Because there is no economic incentive for waste management per se, the government must somehow subsidize or force this activity.

Despite mistrust of government, most people believe that the government must take the responsibility for ultimate disposal of the wastes.

NO SYSTEM HAS, IN FACT, BEEN IMPLEMENTED FOR DISPOSING OF HIGH LEVEL WASTES.

This is interpreted by some to mean that nothing has, in fact, been done. Technologists point out that technology exists which should prove safe upon testing and analysis. One past interpretation is that nothing needed to be done.

THE PUBLIC DOES NOT DISTINGUISH BETWEEN WASTES FROM PAST AND ONGOING MILITARY ACTIVITIES AND THOSE COMING FROM NUCLEAR PRODUCTION.

The current waste management systems are products of government industry crash programs to produce weapon's material as quickly as possible. Wastes are treated as a nuisance and their management was given low status among overwhelming competing priorities. This attitude has carried over in some part to recent waste management activities. The critics of the nuclear program were instrumental in bringing to general attention the crucial importance of radioactive wastes. The management of radioactive wastes is now a political issue not because reasonable adequate technological means for disposal are nonexistent, but because such means have not been deployed.

THERE ARE THREE TIME HORIZONS OF PARTICULAR IMPORTANCE IN DEALING WITH RADIOACTIVE WASTES.

The first of these horizons (5 to 10 years) is fixed by the urgent need for some viable solution to the problem of the disposal of radioactive wastes. It is said with conviction that putting off deciding on a solution is morally indefensible; it is certain that any delay is a cause of difficulty for the industry.

Second, there is little trust in the stability of social institutions for periods of more than a few centruies. At issue is the question of how long man-made structures or institutions can be relied on. Most agree that it would be better not to rely on them; a few have no qualms regarding such reliance; and almost none feels able to predict regarding length of institutional stability.

Finally, there is considerable distrust of predictions beyond a few thousands of years even for geological disposal. Reasons cited include uncertainties regarding demography, land use, climatic change, earth movements, etc.

Long-term considerations of safety (after emplacement in deep geological formations) are seen as most important by a broad range of individuals. And yet, judgments about long-term safety are the most uncertain.

THERE ARE TWO POSSIBLE SCALES FOR THE GENERATION OF WASTES:

- FISSION POWER AS AN ESSENTIALLY PERPETUAL SOURCE, WITH PERPETUAL GENERATION OF WASTE;
- FISSION POWER EVENTUALLY DISPLACED BY OTHER SOURCES, RESULTING IN A LIMITED QUANTITY OF RADIOACTIVE WASTES.

If fission power is transitory, we deal with a finite waste problem. If it is a perpetual source, a steady state will be reached in the inventory of radioactive fission products; but the plutonium inventory in the disposed wastes will increase as long as fission power is utilized (or up to about a million years when plutonium could also reach a steady state).

3. Hazards of Radioactive Wastes

The nature and extent of the hazards deriving from the mere existence of radioactive wastes are in contention today. The public is concerned about the societal implications of plutonium, of the long lifetimes of the hazards, of the invisible action of radiation, and of the fact that the waste legacy endures far beyond the known lifetimes of any industry or government.

THE PUBLIC IS CONCERNED ABOUT THE DIRECT EFFECTS OF RADIOACTIVE WASTES ON MANKIND, NOW AND IN THE FUTURE.

Hazards most often noted include radiation effects on people (e.g., generic, cancer, and other illnesses, etc.), social and institutional impacts (e.g., police forces, social disruptions, land use denial, etc.), and the possibility of deliberate use of the wastes for violence or coercion. Some concern is expressed regarding secondary impacts to the environment (e.g., impact on lower biota).

In discussing levels of radiation which might be acceptable, many refer to natural background levels as an acceptable baseline. Most are willing to accept some losses (e.g., a few lives) for the benefits of nuclear power. But these levels have a broad range and there is no consensus.

THERE APPEARS TO BE EXTRAORDINARY UNCERTAINTY REGARDING THE CONSEQUENCES OF ERROR IN THE MANAGEMENT OF WASTES.

Few systematic attempts have been made to assess the consequences of either a major release of radioactivity or some miscalculation regarding an otherwise safe disposal mode. Those attempts which have been made suffer from several of the failings noted below.

Long-term consequences (e.g., pollution, genetic effects) of (mis)management of radioactive wastes are perceived as irreversible. Many stress that there is a need for retrievability and long-term monitoring and detection. This is a clear demonstration of lack of confidence in any proposed disposal method and is inconsistent with any intention to not rely on social institutions or organizations.

BECAUSE OF THE LONG TIME PERIODS, THERE IS A FAILURE OF CASUAL ANALYSIS--EFFECTS CANNOT BE UNEQUIVOCALLY LINKED TO CAUSES.

There is almost a consensus that absolute safety of the disposal system cannot be proven, at least not proven in the classical sense of tested. Because of the long-term periods, there is no opportunity for feedback, so that errors can be detected and corrected. Testing is impossible in a system without feedback. Feedback can be absent or useless when: 1) consequences are beyond capabilities for detection, 2) consequences occur too far in the future to initiate corrective action, 3) consequences are irreversible, 4) consequences continue for long periods after they are initiated, or 5) prediction of long-term consequences is impossible.

SUBSTANCES OTHER THAN RADIOACTIVE WASTES ARE JUST AS TOXIC AND JUST AS AVAILABLE IN OUR SOCIETY.

This is true, and it is a statement made by the industry to argue for less strict or at least consistent regulation. But experience with other industries (e.g., the chemical industry) indicates that releases do occur, and harm results (e.g., the Kepone spill, arsenic, mercury, nerve gas, etc.). The hope, of course, is to keep the nuclear industry from commiting similar errors.

Nonetheless, the argument is correctly made that the hazards from nuclear power production should be kept in some sort of perspective with respect to comparable hazards. One survey indicated that only nuclear technicians believe that the risks of nuclear power plants are less than those of coal fired plants. In the long run, coal plants may involve risks as high as or even higher than those of nuclear plants. But perspective seemingly does not exist. It is not clear that such a perspective gives any rationale for easing requirements on the nuclear industry. It may, in fact, argue for stricter requirements on other industries.

4. Methodology for Assessment of Radioactive Waste Management

SCIENTIFIC UNCERTAINTIES (e.g., TOXICITY OF PLUTONIUM, GEOLOGICAL STABILITY, etc.) ARE UNLIKELY TO BE RESOLVED BEFORE A WASTE DISPOSAL SYSTEM MUST BE IMPLEMENTED.

The entire question of how scientific uncertainities can be reduced, or resolved, has to be addressed. The subsidiary questions are: What are the criteria for resolution? Who sits in judgment? Etc.

SERIOUS TECHNOLOGICAL ISSUES REGARDING RADIOACTIVE WASTES MAY STILL ARISE JUST BECAUSE THERE HAS NEVER BEEN A LICENSING ACTION FOR HIGH-LEVEL WASTES.

Technological issues in the licensing of reactors are reasonably well defined through the experience of licensing many such plants. No such testing of the technological issues has been taken in waste management.

THERE WILL ALWAYS BE SOME REMAINING UNCERTAINTIES.

The disposal system cannot be tested in the usual sense. There cannot be a guarantee of the performance of the system over the period of time of concern. Thus, our decisions must be based on all relevant factors (technological, societal, institutional, political, etc.).

RISK/BENEFIT ANALYSIS MAY NEVER SUFFICE FOR MAKING DECISIONS CONCERNING NUCLEAR POWER BECAUSE THE DISTRIBUTION OF RISKS AND BENEFITS IS SEPARATED.

However, given that adequate methodologies are used and proper input data are available, present day risk analyses serve the following functions: 1) they are useful for evaluating the relative effect of redundant safety systems, changes in the physical makeup and operation of the system, etc.; 2) they provide a tool for the basic understanding of the system operation under normal and abnormal conditions (this allows one some insight into the proper design of other systems that may have an interface with the system under analysis, e.g., risk analysis of nuclear reactors provides information for emergency response planning in the event of a reactor accident); 3) they provide a basis and focus for continuing discussions on the system.

IN THE U.S.A., OR EVEN IN THE WESTERN WORLD, ONLY THAT WHICH IS QUANTIFIABLE IS TREATED AS REAL.

Conversely, that which is not quantifiable is treated (at least operationally) as unreal. The question is, how can those societal values (unquantifiable) which are clearly important be included (and taken seriously) in a system geared almost entirely to quantified factors? An important note: that quantifiable things are real is just one possible perception.

IN ASSESSING THE RISKS OR CONSEQUENCES OF THE MANAGEMENT OF RADIOACTIVE WASTES, IT IS INADEQUATE TO DEAL ONLY WITH THE STATISTICAL MAN.

It is easy to say that each of us loses a few minutes of his life as a consequence of some radioactive waste hazard, but, in fact, no one will lose only a few minutes; instead a few people die tens of years early. Unlike the statistical model, the real world consists of real people, not of statistical people averaged over time and space. The public may not know exactly what statistical analysis goes into assurance that radioactive hazards mean the loss of only a few minutes of life, but they do know that when someone gets cancer, he loses more than a few minutes.

5. Decision Processes in Waste Management

In reaching decisions regarding the management, there are three elements of importance and concern:

- The substance of the decision (e.g., the technology selected);
- The procedures employed (e.g., environmental statements); and
- The principles used to guide the decisions.

Issues arise in all three elements and some priorities can be assigned.

THE FOCUS OF MOST OF THE CONCERN IS ON THE FINAL DISPOSITION OF THE WASTES.

While greater dangers may be imposed on the public by the treatment and the transportation of radioactive wastes, these elements of the system seem of less concern than waste disposal. The question seems to be less "can we" than "should we" or "will we" implement a disposal system--again, a non-technological question. Retrievability designed into the system appears to show a lack of confidence in that system's performance. Conversely, a lack of confidence may drive us to design the retrievability.

One of the more difficult aspects of the waste management problem is the fact that the system which interacts with the waste management technology is diffuse and complex.

A NECESSARY FIRST STEP IS THE ESTABLISHMENT OF A SET OF DECISION PRINCIPLES.

This is a task for the NRC, but it will necessarily involve inputs from many sectors.

THE REACHING OF A SOLUTION FOR THE MANAGEMENT OF RADIOACTIVE WASTES REQUIRES THAT BOTH THE SUBSTANCE (TECHNOLOGY) AND THE PROCESS (DECISION) BE ACCEPTED.

ERDA estimates that the time available for the development of a technological solution is tens of years. Trust in the decision process must be established perhaps within the next 5 years. A correct decision reached in the wrong manner is unlikely to be accepted.

A FORUM MUST BE PROVIDED FOR DISCUSSION OF ALL PARTS OF THE WASTE MANAGEMENT SYSTEM--TECHNOLOGICAL, SOCIETAL, INSTITUTIONAL, ECONOMIC, POLITICAL, AND ETHICAL.

Views of spokesmen arguing for future generations and for nonbenefiters living today (in other parts of the country and the world) have been given little or no place in the decision process. Technological issues have been discussed, but with the assignment of expertise often made in advance. Societal and institutional issues have been assumed to be answered or have been neglected. Economic and political issues are probably critical. Ethical (and religious) considerations may have unexpected effects on the decision-making process.

With some exceptions, public attention to the issues of waste management has come from the efforts of persons outside the nuclear community. While this action of the adversary public should be encouraged in order to identify the issues, care must be taken that issues be raised also within the decision-making apparatus independent of this public. When public attention wanes, the issues should not be ignored.

NO ADEQUATE PROCEDURES EXIST FOR THE INVOLVEMENT OF OTHER RESPONSIBLE JURISDICTIONS (e.g., STATES AND LOCALITIES) IN THE DECISION-MAKING PROCESS.

The Atomic Energy Act gives the authority to the Federal Government. However, in the case of waste disposal, local jurisdictions have already demonstrated that they will have a powerful and justified impact on the decisions. That procedures exist is not argued. What is in contention is the adequacy of the procedures.

WE OWE SOMETHING TO FUTURE GENERATIONS.

This is a frequently stated precept. Some of the debts are:

- Not limiting their actions;
- Not spreading our risks to them without concomitant benefits;
- Not overly limiting their resourse base; and
- Not imposing social systems on them.

Despite this stated precept, we conclude that past actions both here and abroad indicate that a higher value is placed on present life, health, and quality of life than is placed on benefits to future generations.

Most agree that the future cannot be perfectly safe from our actions, but many say that it should be relatively safe. However, there is clear indication that in any circumstance where present government and industry might suffer costs from assuring benefits to future generations, future generations will have to take their chances. That is, it seems impractical to expect people today to take risks or to forego benefits in order to avoid hazards to or provide benefits for future generations. But what we do owe future generations is our best effort now.

WEIGHTING FUNCTIONS IN THE RISK/BENEFIT EQUATION WILL CHANGE WITH TIME, AND THUS WILL NOT BE THE SAME FOR FUTURE GENERATIONS AS THEY ARE NOW, NOR WILL THERE BE A CONSENSUS ON WHAT THEY SHOULD BE AT ANY GIVEN POINT IN TIME.

We cannot be sure that future generations will desire what we now desire. However, the assumption under which we must operate is that present values will persist.

WE PROVIDE THE BASIS ON WHICH FUTURE GENERATIONS MUST ACT, BUT WE CANNOT DICTATE THEIR COURSE OF ACTION.

There is no way in which we can commit future generations even to know what we have done. We can provide indicators of what we think they should do or beware of, but we cannot commit them to doing it. To the extent that the base is fixed by us, we do bound range of future actions, but we do not dictate any given action. Thus, if we perceive an action to be necessary, we must perform that action now.

TODAY THE PUBLIC DOES NOT TRUST THE DECISION-MAKING PROCESSES OF GOVERNMENT AND INDUSTRY.

This has been documented often. It is apparent that segments of the public do not trust the nuclear industry (and other regulated industries). Development of technological procedures for disposal will require the identification and involvement of the various publics with a stake in the decision regarding the deployment of those technologies. In fact, all groups with an established stance on the issue or a stake in the outcome desire to control the decision. This strongly indicates that the decision is primarily political, not technological.

Whatever the decision, there must be a climate of acceptance. Regulations (or decisions) will not hold unless they are politically acceptable--to both the power holders and to the public at large.

THE COMPLEXITY OF THE PROBLEM OF RADIOACTIVE WASTE MANAGEMENT (LIKE THAT OF MANY OTHER TECHNOLOGICAL PROBLEMS) MAKES IT DIFFICULT TO ACHIEVE AGREEMENT.

One of the serious uncertainties deriving from the long periods of potential hazard is the extent of the boundaries of the system which must be treated in assessing the proposed solution. Societal, political, economic, institutional, and ethical problems are a part of the considerations.

There is thus no way of knowing at this time whether or not we have included all of the relevant issues and concerns. Historical evidence leads us to the belief that we have likely forgotten something. With uncertainty about the specifications of systems' boundaries, the application of usual cost/benefit methods for assessing proposed solutions become questionable.

Acceptability is difficult to establish in the face of controversy. Expertise is difficult to evaluate. Actions must be taken on the basis of judgments that are less than certain.

THERE IS A GREAT NEED FOR CANDOR.

Assurances that there is no real waste management problem simply are no longer adequate. Where there are uncertainties (and there are some), they must be dealt with as such. To paraphrase one consultant, the basis of distrust of the nuclear technology is (in part) the failure of nuclear technologists to answer questions.

THE OLD MODEL FOR DECISION-MAKING IN THE NUCLEAR PROGRAM IS THAT THE GOVERNMENT HIRES EXPERTS TO MAKE THE DECISIONS AND THEN TELLS THE PUBLIC WHAT IS GOOD FOR IT.

This leads to the problem of deciding which expert to believe. The evaluation of expertise is not easy. We must now recognize that the decisions regarding the management of radioactive wastes must be made in a larger arena, not just by experts (either in the industry or among the critics). The new model for decision-making must be broadly based, e.g., the NEPA process.

THERE ARE INSTITUTIONALIZED POSITIONS WHICH ARE FORCED BY THE POSITION OF THE INDIVIDUAL.

An industry spokesman cannot allow himself to doubt his ability to handle the wastes because it weakens the argument for deployment of nuclear facilities. A research worker must consider the issue as a problem in order to receive funding for his work. Those in control of the budget must ask, "Can it wait?" Those charged with development of the technology must find that some of the technology still needs development. The regulators must not move ahead in the light of the uncertainties noted by the above groups. The critics can accept no solution to the waste management problem without weakening their argument against the nuclear problem as a whole. This is a stalemate only until someone moves.

6. Problems of Implementation of a Waste Management System

NO TECHNOLOGICAL SYSTEM IS SELF-IMPLEMENTING.

Past failures of proposed radioactive waste management systems have stemmed in large part from neglect of nontechnological necessities in the implementation of the systems. Societal, political, economic, institutional, and ethical factors must be considered. Even a perfect technological system is useless unless effectively implemented. Failure of managerial decisions must not be confused with failures of the technology.

THE MAJOR WORK IN WASTE MANAGEMENT IN RECENT YEARS HAS BEEN DIRECTED TOWARD IMPROVING THE TECHNOLOGY, NOT TOWARD IMPLEMENTING OR DEPLOYING THE SYSTEM.

This is changing with the FY 77 ERDA program and budget. But again we stress that the system is not self-implementing. Its deployment is neither strictly a societal matter. More than a technological solution is required to solve the radioactive waste problem.

THE CREATION OF FAIL-SAFE ORGANIZATIONS SEEMS TO BE IMPOSSIBLE.

The Organizations which must be set up and maintained to carry out the waste management functions will inevitably be less than perfect in design and in operation. Past actions of the AEC, regulatory instability, and political uncertainty have led to uncertainty and lack of confidence in implementation.

COSTS AND BENEFITS SHOULD BE DISTRIBUTED EQUITABLY.

This is a statement often made by the critics of any program. It is particularly effective in attacking the nuclear program because the risks (cost) of radioactive waste cannot be assigned to any limited time period (because of lack of predictive capability) nor to entirely specifiable individuals or groups. There are no direct benefits of the wastes; only the use of nuclear power is a benefit. The wastes will ultimately (geographically and in time) be potential hazards to people other than those who derived benefits from their production.

CRASH PROGRAMS HAVE NOT BEEN ENTIRELY SUCCESSFUL.

Examples of crash programs in waste management are Hanford, NFS, and Lyons. An example in another area is catalytic converters for automobile engines. Despite its drawbacks, we find ourselves in a situation regarding radioactive wastes in which a crash program is virtually demanded.

THERE IS NOT ONE BEST WAY.

We offer this as a judgment based on historical, institutional and technological factors.

THE VERY CALLING OF THE MATERIALS "WASTE" IS A STRONG DETERMINANT OF HOW THEY WILL BE TREATED PSYCHOLOGICALLY, INTELLECTUALLY, AND PHYSICALLY.

This has been observed or can be inferred throughout human activities including the nuclear industry and the weapons program. Waste has not received the best treatment, and it may be that the public feels vaguely that anything called "waste" will not get the most careful handling.

THE BACK END OF THE FUEL CYCLE (OR AT LEAST WASTE COLLECTION, TREATMENT, STORAGE, TRANSPORTATION, AND DISPOSAL) IS NOT NOW, AND WILL LIKELY NEVER BE, CONVENTIONALLY PROFITABLE.

To date there has developed no market for the byproducts of nuclear fission (except plutonium for weapons and possibly as a fuel) to make the treatment of wastes economically attractive. However treated, some residue of the wastes will have no commercial value and will continue to be a cost to industry rather than a benefit.

IN THE PAST, GOALS AND MANAGEMENT TECHNIQUES HAVE BEEN SET BY BUDGETARY CONSTRAINTS AND BUREAUCRATIC DELAY.

The assignment of funds and staff to solve problems of the management of the radioactive wastes has reflected the lack of concern, or the technological optimism, still expressed by spokesmen of the nuclear industry and the technological community. They say that the problem can be solved easily and that we have plenty of time. Thus minimal funds have been allocated, and the methods currently used and proposed reflect the lack of sufficient funds.

FOR ALL ENGINEERED SYSTEMS THAT HAVE BEEN MAINTAINED FOR A LONG TIME (e.g., AQUEDUCTS) THERE HAVE BEEN POSITIVE ECONOMIC INCENTIVES (AS OPPOSED TO MERE RISK AVOIDANCE).

Given the low profitability of radioactive waste management, it is tempting to conclude that only passive systems that require no maintenance or monitoring for the management of wastes should be considered.

TECHNOLOGICAL UNCERTAINTIES ARISE FROM THE FACT THAT SEVERAL OF THE STEPS IN THE WASTE MANAGEMENT SEQUENCE ARE AS YET UNPROVEN AT INDUSTRIAL SCALE.

This is the position of ERDA and the industry. It clearly makes it difficult for the regulatory body to decide about the acceptability of those steps.

CARE MUST BE TAKEN THAT THE PROBLEMS OF GOING TO INDUSTRIAL SCALE ARE ANTICIPATED.

There is a qualitative difference between the problem in 1976 and the problem in 2000. The quantity of waste existing today could perhaps be carefully dispersed in the environment without exceeding presently accepted concentrations. At some time in the next century, the quantity of wastes will be too great to dispose of by dispersion. Institutions capable of handling present quantities may not be able adequately to handle waste from an industry much larger than the present one. We may foreclose some options merely by going to full scale.

THE NUCLEAR SYSTEM IS A WORLD SYSTEM.

"....pollution flows with the waters and flies with the winds;...it recognizes no boundary lines and penetrates all defenses;...it works irrepairable damage alike to Nature and Mankind--threating...the life of the seas; the flora and fauna of the earth, the health of the people in cities and the countryside alike:..it can be adequately controlled only through international cooperation." (Comager)

This is an important thought expressed by many people. They maintain that the U.S. can and should play a leadership role in the development and use of nuclear technology, and that both national and international regulations are required.

GOALS FOR NUCLEAR WASTE MANAGEMENT

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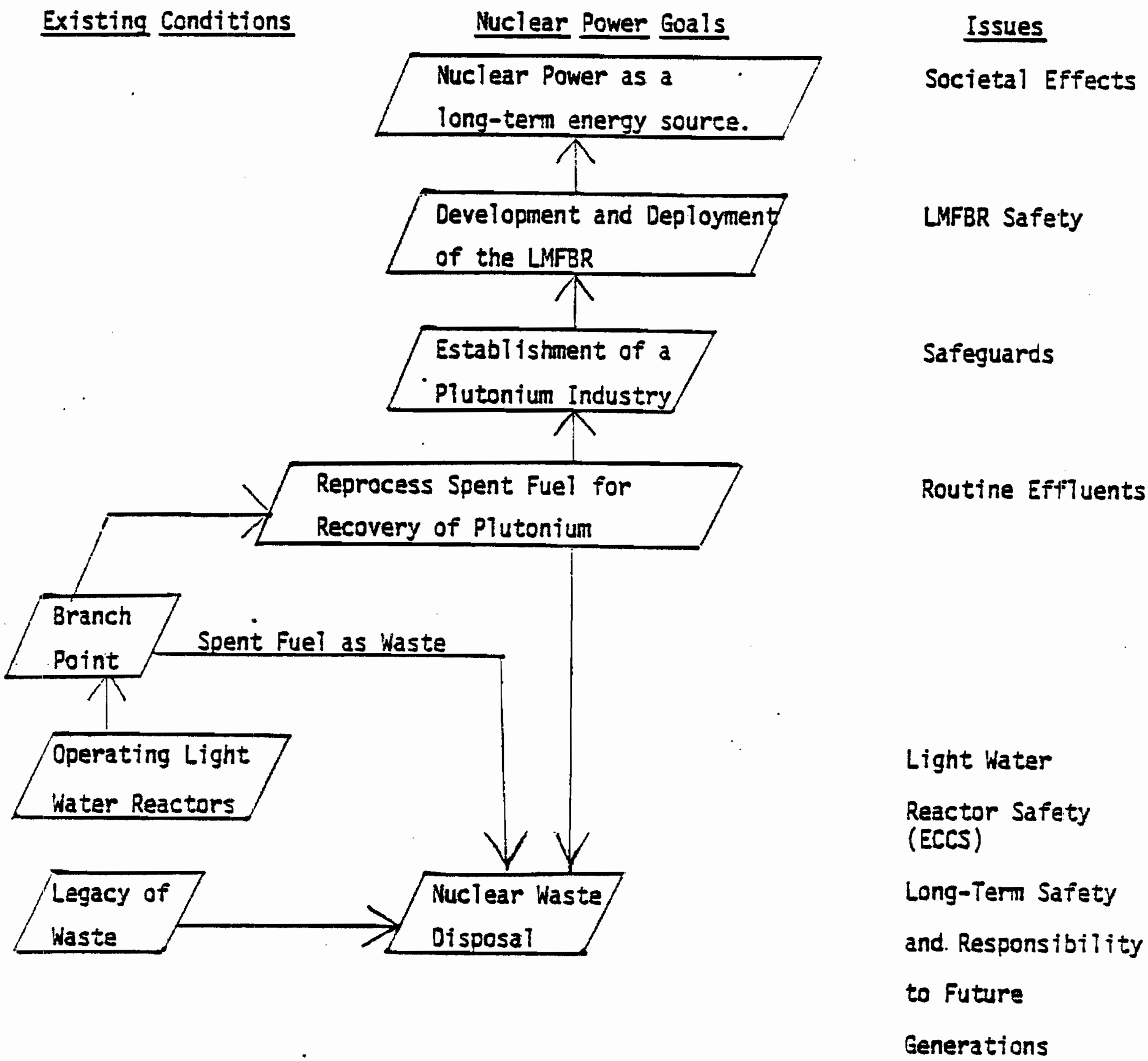
GOALS FOR NUCLEAR WASTE MANAGEMENT

FRONTISPIECE

THE RELATION OF COMMERCIAL NUCLEAR POWER GOALS TO PUBLIC ISSUES



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Richard A. Watson

1. INTRODUCTION

Many argue that the establishment of a commercial nuclear power industry makes sense only when it is viewed as a long-term energy source. From such a premise a number of arguments logically follow. To achieve such a long-term goal with nuclear power (fission) it is mandatory that the liquid metal fast breeder reactor (LMFBR) (or some other means of using fertile isotopes such as U-238) be developed and deployed. Existing light water reactors (LWR) are inefficient utilizers of natural uranium and would exhaust known reserves within several decades. The LWRs, however, can provide the initial fuel loads (plutonium) for the LMFBRs. If the LMFBR is the system deployed, plutonium industry must be established. This industry would provide plutonium processing, fabrication, and safeguards. One technically desirable manner of establishing this industry is through plutonium recycle in LWRs. This allows the industry to be built to fill a demand rather than to make the demand. Thus, the establishment of a long-term commercial nuclear power industry based on LMFBRs hinges on the initiation of reprocessing of spent fuel from LWRs for the recovery of plutonium. And therefore the future of the commercial nuclear power industry rides on the decision concerning fuel reprocessing (Frontispiece).

It is on the assumption that the nuclear industry will proliferate as described above that the problem of managing nuclear wastes becomes especially critical. In every step of the nuclear fuel cycle--from mining to reprocessing, and particularly in reprocessing--nuclear wastes are generated that must be collected, confined, treated, stored, and disposed of to assure that they will not enter the biosphere in amounts and concentrations that would pose physical hazards or societal strains on the human environment. The need to dispose of these wastes presents very serious technological problems because of their intense and long-term toxicity, and because they range from large volumes with low radioactivity to very small volumes with extremely high radioactivity.

Establishing a publicly, politically, economically, and technologically acceptable waste management system for the nuclear fuel cycle is a necessary, but not sufficient condition for accepting the nuclear program as a national energy option. (Other issues such as safeguards, LMFBR safety, and accident liability would also have to be resolved.) However, it is obvious that lack of acceptable waste management systems could seriously jeopardize the future of the nuclear program.

The existence today of large quantities of nuclear wastes provides an impetus to implement a waste management system immediately. However, any solution of this current waste problem should not be taken either as an indication that the impending waste problem is or can be solved, or as a necessary model of how the problem of future wastes should be solved. It is essential to recognize that the waste problem is twofold. We must implement waste management systems to manage existing nuclear wastes because they <u>do</u> exist, and we must assure ourselves that safe systems can be implemented to manage the wastes from a vastly expanded nuclear program before proceeding with that program.

1.1 <u>Nuclear Wastes</u> An operating definition of nuclear wastes currently used by the NRC and taken as a starting point for our investigations is as follows:

> <u>Nuclear wastes</u> are those radioactive materials which are of sufficient potential radiological hazard that they require special care and which are of no present economic value to the nuclear industry.

This definition allows flexibility with respect to increasing knowledge about radiological hazards and developing technology. However, it puts the burden of primary definition of nuclear wastes on fluctuating economic factors rather than on the permanent physical characteristics that make the materials hazardous. What is useless waste in one economic and technological circumstance might be a valuable resource in another. Although no non-economic definition of waste is complete or viable, it is imperative for a stable program that management and jurisdiction not be subject entirely to fluctuating market conditions. Thus, given the economic determinant, a basic need for regulation of waste management systems is to clarify procedures so that what is under the management of the Federal government on one day, e.g., is not automatically turned over to private industry on the next, and vice versa.

The word "waste" itself carries implications of worthlessness that may have led government and industry to pay inadequate attention to waste management. The public at large, also, may feel that anything designated as waste will not be managed with the care radioactive materials demand.

Thus it appears that a correlate definition might be valuable, not only to accommodate fluctuations in economic value, but also to assure careful handling. We propose that "nuclear wastes" be defined as equivalent to "nuclear residues" as follows:

> Nuclear residues are radioactive materials that are discharged as waste, and that require special care to prevent them from being presently or potentially hazardous to society.

This definition stresses the permanent physical character and hazardous nature of whatever is discharged as waste, independently of its economic value.

The NRC is responsible for regulating the management of wastes derived from all operations of the nuclear fuel cycle. The wide variety of wastes requires several methods of management. Their definitions are mixed and--like the definition of waste itself-open to interpretation. HLW, decommissioned equipment and facilities, TRU, and LLW are extremely mixed lots. Further, physically similar wastes are considered separately according to whether their production is in military, Federal (ERDA), or commercial facilities. Finally, jurisdiction over wastes varies according to whether the individual radioactive elements are natural in origin or manmade.

This complexity makes management and regulation (and discussion) difficult. It is surely reasonable to assume as a basic premise that for safety and efficiency, physically similar wastes should receive similar management and regulation, whatever their origin. We propose the following, therefore, as a primary goal of the general waste program:

> A new set of definitions of nuclear should be established that categorizes them strictly according to type, degree, and half-life of the radioactive nuclides involved, without respect to origin.

1.2. The Uniqueness of and Fear of Nuclear Wastes

Nuclear Wastes are perceived by most people to be unique in three specific ways:

a. Their toxicity derives from radioactivity that acts invisibly and at a distance to cause somatic and genetic damage.

b. They consist of manmade elements that do not generally exist in nature.

c. They are associated with the devastating effects of the atomic bomb.

Scientists and technologists often point out that other toxic elements, e.g., arsenic, are longer-lived than any nuclear wastes, that some, e.g., botulism toxin, are more toxic, and that the potential hazards of such activities as smoking cigarettes and driving automobiles are much greater than those of failures in nuclear waste disposal systems. That nuclear wastes are not physically unique in terms of toxicity or hazardousness, however, does not remove the unease with which the general public views them. It is clear that from an overall societal standpoint, the nuclear waste problem is not solved merely because the public is physically safe; the public must also be reassured and convinced that it is safe. Some commentators believe that the harm done to society by the fear of things nuclear is greater than the harm that could be done by failure of nuclear facilities. Some go so far as to say that the disruption to individuals and society as a whole caused by this fear is grounds for curtailing the nuclear program entirely.

Nuclear wastes are unique in the threefold ways indicated, and fear of things nuclear is general in society. However, it is not immediately obvious that a majority of the public has this fear, or that it affects many of those who do have it very seriously. This fear, in fact, can have an extremely salutory effect. As great care is taken with nuclear wastes, and the public becomes more familiar with comparable hazards, perhaps demands will be made to treat other toxic elements and industrial wastes with the managerial care required for nuclear wastes.

1.3 Critics of Nuclear Waste Programs

Present public concern about nuclear waste management had largely been raised by critics who are not necessarily opponents of the nuclear program. Prior to this there were people in the AEC, ERDA, NRC, and the nuclear industry who understood the gravity of the waste problem, but none of them were able to bring it to the fore. The critics stress something that everyone concerned with the nuclear program knows: whether or not we go ahead with the nuclear program, existing nuclear wastes must be managed safely.

This places some opponents of the nuclear program in a dilemma. They understand that present wastes must be disposed of, but they also realize that the safe and adequate handling of existing wastes would provide an argument for proceeding with the nuclear program. Some opponents, then, reject all waste management plans on principle. We cannot accept this extreme position as viable. Although one might argue that the hazards of currently existing wastes are small in comparison to the amounts that will be produced if the nuclear program proceeds, and that existing wastes could be ignored at no great jeopardy to mankind, we believe that the hazards of existing wastes are serious enough that waste management programs must be developed. However, we note that successful disposal of existing wastes may in fact not be adequate to justify the production of much larger quantities of different types of waste.

Opponents of the nuclear program who reject some or all of the above assumptions apparently represent a minority of the American public. They recommend that the nuclear program be halted so no more wastes will be produced, in part because of honest beliefs that nuclear wastes cannot be managed safely. Although it is true that no waste program has been demonstrated to be entirely safe (and cannot be in any absolute sense), the majority of scientists, technologists, politicians, and the general public seem to be in favor of going ahead with the nuclear program. Thus, we conclude that it is not practical at this time to consider the abandonment of the nuclear program as a way of solving (or curtailing) the waste problem. We proceed on the assumption that the nuclear program will continue, and that nuclear wastes that must be managed will be produced in increasing volumes in the years to come.

1.4. The Immediate Necessity for Nuclear Waste Management Systems

The U.S. Government made a commitment in 1946 to develop and deploy a commercial nuclear power program. Today this commitment is represented in part by 59 licensed and operating commerical light water reactors and a large national research and development budget for the liquid metal fast breeder reactor. If the national commitment to the nuclear program does not change, then the United States will have as many as 200 to 500 commercial reactors in operation by the year 2000. This possible increase highlights the urgency of developing management systems to handle wastes from such a large industry.

Systems are also needed to manage existing wastes. In addition to wastes from the presently operating commercial nuclear power industry, the U. S. has a large legacy of nuclear wastes from the development of nuclear weapons and military reactors. Therefore, regardless of the future of the U.S. Commercial nuclear power industry, a coordinated waste management program for existing wastes is an immediate national necessity.

To some degree, neither opponents nor advocates of the nuclear program wish to partition the waste problem into separate consideration of existing and future wastes. Both believe that successful implementation of a program for existing wastes will further the nuclear program. This is true in a political context, for success with existing wastes would reassure the public. However, the physical types of future wastes may be quite different from, and will be produced in much greater quantities than, existing wastes. Consequently, we reiterate that a solution of the existing waste problem in itself neither solves the problem of future wastes nor necessarily stands as a model for future solutions. In any event, we should go ahead with the disposal of existing wastes.

1.5 Nuclear Waste Management in a Societal Context: 15 Tentative Assumptions

Nuclear wastes can be managed safely only with careful integration of technological and societal factors. From a technological standpoint, the basic goal is to develop and implement techniques for premanently isolating nuclear wastes from the human environment. Some technologists believe that solving the waste management problem is simply a matter of engineering, and several methods have been designed.

From a societal standpoint, however, the technological solution to the problem, while necessary, is secondary and insufficient. In the societal context, a technological solution must be not only effective, but also acceptable in political, economic, moral, aesthetic, and in overall societal terms. It is our observation that the inadequacies of America's nuclear waste programs so far have derived not from poor technology, but from poor politics. Inadequate attention has been paid to public attitudes not merely about waste programs, but about the nuclear program as a whole.

Whether waste management has been neglected because it was not glamorous or exciting or profitable, or because presumably it could be postponed with no physical ill effects, many critics today point to this neglect as evidence for the societal irresponsibility of advocates of the nuclear program. And one reason waste programs are delayed today is the effective intervention of opponents of the nuclear program. It seems clear, therefore, that a solution to the total nuclear waste management problem requires not only technological means, but also public or political or societal acceptance of such means.

Even though the technological and societal aspects of the problem cannot be separated in actuality, they can be examined separately for the purpose of isolating principles. In doing so, we have derived the following basic framework of 15 tentative assumptions:

From a technological viewpoint

a. There are no natural restraints on solving the problem of isolating nuclear wastes from the human environment for as long as 500,000 years.

b. Several methods of isolation appear-with a high degree of probability--to be safe and viable according to present scientific and technological knowledge.

c. Given the money and the go-ahead, technologists and engineers could deploy these waste management methods on an industrial scale.

From a political viewpoint

d. A large commitment to the nuclear program has already been made, and considerable volumes of nuclear wastes that must be managed already exist.

e. The safe management of nuclear wastes is a necessary (but not sufficient) condition for the continuation of the nuclear program.

f. Government and industry will work together to develop safe nuclear waste management systems.

From an economic viewpoint

g. If nuclear waste management is conventionally profitable, private industry will develop and deploy it.

h. If nuclear waste management is not conventionally profitable, the Federal government will sudsidize it.

i. So far, management of HLW and TRU has not been conventionally profitable although some LLW management enterprises have been.

From a moral viewpoint

j. Political and economic factors being the same (or relatively negligible in difference), the more conventionally moral form of waste disposal will perhaps be chosen, but otherwise probably not.

From an aesthetic viewpoint

k. Political, economic, and moral factors being the same (or relatively negligible in difference), the more conventionally aesthetic form of waste disposal will perhaps be chosen, but otherwise probably not.

From an overall societal (national) viewpoint

l. High energy is essential to the maintenance of America's high technology society and to national survival.

m. Most Americans will not voluntarily accept lowered standards of living in the cause of conservation, underdeveloped nations, or future generations.

n. Americans (and most other people) desire an increase in the production and use of high energy.

o. The nuclear program is generally believed to be the most promising and furthest developed method of increasing the production of high energy.

As remarked above, we did not begin with these assumptions, but derived them from our reading, interviews, and analyses. They are subject to revision or rejection, but we feel confident enough in them at this point to assert that the American public in general as represented by elected representatives, industry spokesmen, and the majority of ordinary citizens would accept the following as the primary goal for nuclear waste management:

> We should develop technological methods of isolating nuclear wastes that are physically safe and societally acceptable, for the purpose of furthering the nuclear program.

I. FINDINGS ON NUCLEAR WASTE MANAGEMENT

2. FINDINGS ON THE TECHNOLOGY OF NUCLEAR WASTE MANAGEMENT

The key technological notion is efficiency. The basic technological problem is to design and to implement efficient technological systems. Without a technological solution to the nuclear waste management problem, there is no safe nuclear program.

2.1. Introduction

Almost everyone agrees that existing wastes must be isolated from the human environment for as long as 500,000 years. If these and nuclear wastes yet to be produced cannot be safely isolated, then it is not safe to proceed with the nuclear power program. All commentators agree on this point, and most of them now perceive that this makes the waste management problem pivotal in the great nuclear debate. This realization has made some proponents of the nuclear industry assert without qualification that the waste problem can be solved, while it has made some opponents deny on principle that it cannot. Clearly, how the issue is resolved will have a basic influence on the future development of the nuclear power program. Given that delay is to the political advantage of opponents, and to the economic disadvantage of proponents, opponents seek extended debate while proponents seek immediate resolution.

> The basic technological question in this larger debate is: Given present scientific, technological, engineering, and industrial capacities, can radioactive wastes be safely isolated from the human environment for as long as 500,000 years?

Technologists and industrial spokesmen answer yes. The conclusion we draw from our investigations is that the majority of scientists, technologists, industrialists, elected representatives, and general public believes that nuclear wastes can be safely isolated. They are also in favor of the nuclear power program. Obviously, there can be no safe nuclear industry without safe waste management systems. It thus appears that the majority desires that waste programs be implemented. A major, general regulatory goal, then, is to regulate so as to assure safe management of nuclear wastes.

2.2. The Containment of Nuclear Wastes.

The key to safe management of nuclear wastes is containment. If nuclear wastes are to be isolated from the human environment, then immediately upon their production they must be collected and contained. The first technological problem in waste management is thus collection. And at the point of collection and thenceforth--from collection through treatment, storage, transportation, and final disposal--nuclear wastes must be contained. The technology of safe containment, therefore, is primary to nuclear waste management.

Most nuclear wastes are not in fact safely contained today. HLW and TRU are at present stored in tanks that do not isolate these wastes safely and permanently from the human environment. LLW, mill tailings, and decommissioned material also at present are contained in facilities and with methods that do not assure safe and permanent isolation. Despite various leaks in some of these physical systems, however, they could be maintained and managed safely if stable and attentive human maintenance could be assured for several hundred to several hundred thousand years in the future.

2.2.1. The Human Element in Containment Technology

The weakest link in any technological system is the human element. Edward Teller once remarked that no system is proof from fools. And even intelligent, conscientious workers are not infallible. Some human error is inevitable. Further, no human institution has ever lasted as long as would be required if a system actually were to be managed, and no one thinks any will. Even without the evidence of various "impossible" situations caused in nuclear operations by human error, everyone agrees that the human element should be eliminated as much as possible from any system that is meant to be both safe and permanent. Consequently, most commentators believe that those containment phases that depend on human supervision should be passed through as quickly as possible to reach a final and permanent containment mode that is not dependent on human maintenance. Thus, the operational containment problem is to develop safe methods to use during collection, treatment, storage, transportation, and disposal. The ultimate containment problem is to develop a technology of permanent isolation that after deployment is independent of human supervision.

Because of the need for human actions, most people agree that nuclear wastes are more dangerous, i.e., more likely to do harm, during collection, treatment, storage, transportation, and disposal, than they are likely to be after having been emplaced in most contemplated disposal situations. Consequently, not only are accident precautions more imperative during the interim phases than after isolation, so also is development of plans of action in case of accident. In other words, it is not enough merely to develop a technology of containment. A technology or recovery and repair in case of accident--a kind of secondary containment--is required as well.

2.2.2. Nuclear Waste Mobility and Containment Modes

From a containment viewpoint, wastes manifest mobility or immobility according to:

a. Composition (chemically active or passive)

b. Form (solid, liquid, or gas)

c. Container (inert, corrodible, etc.)

d. Physical environment (bedrock, ocean, atmosphere, outer space)

e. Societal environment (stability, level of technology, awareness, etc.).

The technological problem posed by each of these categories is to develop techniques to make the wastes as immobile as possible. Ideally, regulations should be adopted requiring optimal containment in each of the five modes. And again, most people agree that the best situation would be one in which if the first four modes of containment were optimized, wastes would remain permanently isolated whatever the societal environment.

Despite the desire for optimum modes of containment, almost everyone agrees that safety is increased if a variety of final disposal systems are utilized. Proposed disposal methods that have been worked out theoretically or tested as far as pilot plant operation are as follows (in order of generally agreed upon safety and practicality):

a. Bedrock (continental: salt, shale, crystalline, or limestone)

b. Ocean basins (sediment)

c. Bedrock (seabed)

d. Ice caps

e. Extraterrestrial

At present, pilot work is being done only on geologic disposal methods. Variety here is offered by different rock types, and by the choice of continental or seabed disposal. Disposal beneath ice caps and extraterrestrially appears to be much more hazardous than bedrock disposal.

No one believes that disposal (in contrast to storage) of HLW and TRU on the earth's surface or in shallow burial is permanently safe. However, such disposal is thought by many to be practically adequate for LLW, mill tailings, and some decommissioned facilities. Several such LLW disposal facilities are now in operation.

Gases provide a special containment problem. No man-made container can maintain its integrity long enough to confine some radioactive gases through their decay periods. One possibility is to pipe radioactive gases into the natural bedrock confinement areas from which natural gas has been pumped. There is unease about the safety of this method, however. A basic technological problem, then, is that of reducing gases to more stable solid forms.

2.2.3. Redundancy

In such critical technologies as that of nuclear waste management, failure or accident could be catastrophic. For this reason, all systems should be matched by redundant, back-up safety systems. Double-containment for storage provides such redundancy.

Besides redundant mechanical parts, there must be redundant surveillance, as well. The leak that went undetected for 51 days at Hanford in 1973 is an example of why redundancy or double-check procedures are needed for the human parts of the system.

2.3. The Dispersal of Nuclear Wastes

Nuclear wastes might be--have been and are being--disposed of through dispersal in the atmosphere and oceans. Obviously, this is containment on a global scale, for these wastes are confined to the earth. For small total volumes of long half-life wastes, and for small incremental volumes of short half-life wastes, dispersal is relatively safe. There are three reasons, however, why dispersal is not favored as a waste disposal method:

a. According to the linear hypothesis, the carcinogenic effect of radioactivity is proportional to radioactivity whatever its degree. It seems reasonable to assume that any addition of radioactivity to the general environment is hazardous.

b. The carrying capacity for the atmosphere and the oceans is strictly finite. If we have not exceeded capacity already, it is prudent to maintain a capacity for absorption of unavoidable (there is always some release, for perfect containment is impossible), accidental, and military releases of radioactive materials.

c. Radioactive elements dispersed in the general environment tend to be concentrated by biological organisms, so that elements that would be safe if they remained dispersed in the ocean show up in concentrations dangerous for man in fish we eat, and elements dispersed in the atmosphere--such as cesium-137 and strontium-90--show up in human bodies and bones.

Given that in the best of circumstances there will be unavoidable releases that will slowly build up, many observers reject dispersal as a disposal method.

2.4. Partitioning and Transmutation

Wastes can be highly partitioned to separate types and elements as greatly as possible for separate treatment. It is also theoretically possible to transmute many radioactive elements to reduce the volume of HLW and TRU, or to reach a final waste form and composition that can be disposed of most easily and safely. While most observers agree that partitioning and transmutation would be valuable techniques, the technology involved is still mostly theoretical. Some of the problems involved are extremely difficult, and there is ground for arguing that the technological investment required (not to mention the economic) is greater than the advantages that would be gained. Nevertheless, transmutation remains a very attractive possibility, for extensive transmutation would reduce the primary containment problem.

2.5. Implementation of Nuclear Waste Management on an Industrial Scale

Several HLW and TRU disposal methods are theoretically sound, and some are in pilot plant stages. LLW disposal systems already exist on an industrial scale. However, no permanent methods of nuclear waste disposal have been firmly chosen as yet. Once methods are chosen, major engineering problems of going to industrial scale will remain. Three things must be remembered as waste management methods move from pilot plant to industrial scale:

a. Mere increase in size and quantity may raise problems and cause effects that were unanticipated. These methods can be implemented on an industrial scale only empirically and through experience. Thus, some uncertainty will always remain about their safety until they have been fully operational for some time.

b. It does take time to implement a method on an industrial scale.

c. Deployment of any method on an industrial scale may for all practical purposes preclude implementation of other possible methods.

Perhaps the most difficult thing for the general public and elected representatives (and for that matter, some scientists and technologists) to keep in mind are the differences among scientific feasibility, technological capacity, and industrial deployment. There are enormous gaps between something being possible and its being technologically demonstrated, and between the pilot plant demonstration and engineering on an industrial scale. At the present time, there seems to be no scientific reasons why safe waste disposal is not possible. Technologically, a certain amount of pilot testing has been done with favorable results. There has so far been no deployment on an industrial scale, but promising systems do appear implementable. However, everyone must remember this basic point:

Waste management systems are not self-implementing.

Full-scale industrial deployment must be accomplished before the waste problem is solved.

2.6. The Relation of Present to Future Waste Management Technologies

Because it has been possible to delay solving the waste management problem in the past, and because some nuclear scientists and technologists believe it is not yet technologically urgent, there is some ground for the argument that we should delay implementing any extensive or permanent waste management systems now to wait instead for advances in technology. Evidently the belief that future technology would be better led the British for some years to defer the waste problem, although they are addressing it now. If we can contain wastes safely temporarily, why not wait for better technology to develop?

From a strictly technological viewpoint, one answer to this question is that waste storage systems as presently planned are probably safe enough. There does exist an extensive waste management problem now that can be solved adequately--so far as we can tell--with existing technology. As reiterated elsewhere in this report, no system can ever be guaranteed perfect. There would seem, therefore, to be no technological reason for not proceeding.

However, even were we not assured about our present plans, there is an overwhelming reason for proceeding now:

Technology develops only through implementation.

No amount of theoretical speculation will result in better technology unless many methods are given pilot tests and some are engineered at industrial scale. Hence, even if our present schemes are inadequate, they should be put on the line, because this is the only way their inadequacies can be exposed and corrected.

2.7. Storage and Retrievability of Nuclear Wastes

Wastes must be stored at various times between their collection and final disposal. Storage technology thus must be developed. Storage itself can be imposed on the system merely by the fact that it takes time to collect wastes. Wastes are also stored to wait for transportation, or for accumulation, or for facility availability, and so on. Wastes may also be stored to give short half-life nuclides time to decay, or to allow the partial decay of high-heat producing nuclides. Finally, existing HLW and TRU are necessarily being stored because no permanent disposal facilities have been built.

It is prudent to build technological systems so that one can reverse the effects they cause, or at least so the direction or impact of those effects can be changed or modified. This is why retrievability is attractive. Certainly retrievability (basically: relatively easy accessibility) should be a feature of all stages of the waste disposal system until after final disposal. The point of final disposal is to make retrievability (i.e., easy access) as difficult as possible.

Dispersal and transmutation are irreversible modes of disposal, so retrievability is ruled out if they are used. As for currently preferred bedrock disposal methods, in principle retrievability is ruled out because the methods are meant to provide final depositories. In fact, however, wastes buried deeply in bedrock could be retrieved with existing technology if we wished to do it. By designating these depositories as permanent, we indicate that we do not anticipate any need or desire to retrieve the wastes.

Waste storage implies retrievability. Thus, the proposed Retrievable Surface Storage Facility (RSSF) was not designed to be permanent, and so was not called a disposal facility.

Plans for the RSSF have been shelved at present, partially because critics fear that it might become a permanent disposal site, as perhaps has happened at Hanford. This leads to a basic principle about storage:

<u>Any long-term storage facility should be designed so that if it is abandoned, the result is a situation that fits the criteria for permanent disposal.</u>

2.8. <u>Uncertainties of Waste Management Technology</u>

It is the nature of scientific "facts" to be uncertain. That is, even highly confirmed statements in science, e.g., even the law of falling bodies, are continuously subject to empirical tests which may lead to their revision or rejection and replacement. Einstein caused a revolution in physics by challenging "absolute laws." In fact, no scientific law is absolute, and Einstein's discoveries led to the change from classical to quantum physics.

The general public--and even some scientists--often view scientific facts as certain. This leads them unrealistically to ask for certain proof, e.g., that a bridge will not collapse, or that radioactive wastes will not escape from sites of final disposal. No such <u>proof</u> can be given. What can be provided are statements of probability based on analyses of known physical characteristics, past experience, and projected situations. There is no absolute guarantee--no proof--that any technological system will perform as predicted. But we can predict with very high probabilities.

The uncertainties of various proposed waste management systems are not disturbing on the scientific level, for here the only uncertainties are those philosophical ones that underlie science as a whole and which seldom if ever disturb the practical affairs of mankind. On the level of technological development, there are various uncertainties about the performance of containment systems, but many of these--e.g., matters of materials strength, waste mobility, and so on--are amenable to standard pilot project testing. Many uncertainties of implementation at industrial scale also can be reduced as engineering proceeds. More care is being paid to anticipating hazards from these uncertainties in the nuclear industry than in any other industry. Nuclear facilities are designed to be safer than those of almost any other, and the likelihood of nuclear workers being injured on the job, e.g., is several orders of magnitude less than the likelihood of their being injured in an automobile on the way to work.

Few people would disagree with the above. There is, however, a requirement the nuclear industry must meet that makes it virtually impossible to give ordinary probabilistic assurances about performance. Specifically for nuclear waste management, everyone would like to have some assurance that the systems will perform over the allotted time periods, i.e., from a few hundred to 500,000 years. The basic problem is that these time periods are so long that we cannot test the systems directly, nor do we have in existence analogous manmade systems that have lasted long enough for us to extrapolate from them. What is basically missing in our projections about waste systems, then, is feedback from systems that have operated for a long long time, to tell us how the system is doing, how reliable it is, what needs modification, and so on.

For systems designed to contain wastes of short half lives, we can project with fairly high probability. This is because we do have experience with similar systems over periods of 30 or more years, we have experience with the basic technology for longer periods than that, and we have knowledge of engineered systems that have lasted for hundreds of years. <u>Technologically speaking, we probably need be much less worried about containing wastes for 300 to 500 years</u> than about a major bridge or building collapsing. And in all probability, failure of such a waste system--because of secondary containment precautions--would be less catastrophic than, say, the collapse of a major bridge.

For systems designed to last much longer than 500 years, we have very little experience to go by. In theory, disposal by burial in deep geological formations should be safe even for millions of years. Our knowledge of geology is probably adequate enough to reassure us both that such disposal is safe, and that almost all varieties of failure would be minimal in consequence. However, thousands of years is a long time. Anything that is not against the laws of nature could happen, such as a volcanic eruption taking place or a giant meteorite landing directly on a deep disposal site, mobilizing the radioactive wastes. These possibilities, while remote, bear consideration. They are the major physical (as opposed to societal) reasons for concern about the uncertainties of the waste program.

It is clear, therefore, that no waste disposal system can be fail-safe even in a technological sense, let alone when human performance (or specified lack of it) is part of the system. That is, there is uncertainty not only because of the complexity and longevity of the system, but also because the system is open. The ultimately effective boundaries of the containment system--as remarked above--is the earth itself, or, as the meteorite example suggests, the solar system. Anything physically possible <u>could</u> happen. One requirement that cannot be met by any technological system, therefore, is assurance that it be perfect. Any requirement that nuclear waste systems be assured to be absolutely fail-safe before they are implemented, therefore, is equivalent to forbidding the implementation of any system at all.

2.9. Evaluating Technological Claims

Contradictory claims about waste management technology appear to have been made by equally qualified scientists and technologists. In fact, point by point comparison both of qualifications and statements would probably show that statements on both sides are hedged, and that individual qualifications vary greatly. Furthermore, it is commonplace to insist that experts in one field are not necessarily more (or less) competent in other fields than laymen, and to insist, e.g., that pronouncements of eminent biologists on physics be given the same scrutiny one would give pronouncements of eminent physicists on biology. That is, what the expert says about a field outside the area in which he gained his reputation may be correct, but one should not accept it merely because of his reputation.

Having said this, we note that in the great nuclear debate, the scientific facts are often not in contention. Determinations of the incredible toxicity of radioactive wastes made by biologists are not necessarily disputed by physicists. But when some biologists say that the nuclear industry should be curtailed because nuclear wastes are so dangerous, many physicists retort that there are adequate methods for containing these wastes so that they will cause no harm. Taking into consideration the various possibilities of biological concentration and distribution after disposal, most scientists--especially those closest to the problems involved--believe that wastes can be safely isolated.

How does one evaluate the experts? It is clear that within the scientific and technological community, a perfectly valid and operating method exists. The claims that fit best with accepted bodies of scientific knowledge, and which repeatedly bear out testing, are those accepted by the specialized community as a whole. And in science and technology, experts are accustomed to accepting the statements of the most prominent experts in any given specialized field (who almost always represent a majority of experts in that field). Most scientists and technologists believe that nuclear wastes can be disposed of safely, not because all of them are experts in this area, but because most of those who are experts in waste management matters believe it can be done.

While it is clear that there are real disagreements among highly qualified experts in the waste management field, the overwhelmingly majority attitude of the primary workers is technological optimism about waste management. While all these people could be wrong, it would be to go against all past procedural methodology to conclude that wastes cannot be disposed of safely merely because a few experts think they cannot be. There may indeed be reason for accepting the cautions of these few, but this reason is more likely to be political than scientific or technological.

2.10. Risk Analysis in Nuclear Waste Management

2.10.1. Quantitative Risk Analysis

Risk analysis is a method for evaluating the effects of technological systems under normal and abnormal conditions, and for comparing the effect of different systems with respect to the possibilities of their harming human beings. Results of risk analysis are useful for improving internal design, for anticipating interactions with the bounding environment and other external systems, for choosing among alternate systems, and finally for planning responses in case of failure or accident. It is a way, also, of comparing systems in which the risks of failure or accident are great but the results small, with those in which the risks of failure or accident are small but the results great.

A necessary requirement for risk analysis is that all parameters of the system(s) under consideration be represented in the same metric. For modern technological systems, this metric is ubiquitously available because the language of science and technology is mathematics. From a purely technological viewpoint, all characteristics of present-day technological systems are represented in quantitative terms, and thus are directly comparable. The only part of technological systems that is debatably quantifiable is the human factor which is, given its intractable qualitative character (i.e., human beings are erratic and their behavior is not consistently predictable), the human element is sometimes ignored in the risk analysis of technological systems. This limitation on risk analysis is discussed in Section 2.10.2.

Risk analysis is used to evaluate hazards arising from wastes during two phases of the program, 1) during their production, collection, treatment, storage, transportation, and disposal, and 2) after final deposition. The greatest immediate risks to human health are to workers during the handling of wastes, and this is a primary reason for the importance of the technology of containment. It is also the reason for the need of an extensive remote-handling technology, for the wastes are so toxic that they cannot be handled directly. The general public is threatened during waste handling only by the danger of failure or accident, and thus risk analysis is used to determine both the possibility of and the effects of failures and accidents. Most of this work is quite straightforward, and the hazards and difficulties are understood and in large part compensated for.

Sometimes ignored, but of particular importance, are uncontrolled releases of radioactive materials into the general environment during the basic operations of nuclear facilities. These nuclear wastes are necessarily dispersed into the environment (as remarked above, because no technological process or facility can guarantee perfect containment). Risk analysis is used to measure the hazards of these effluents. It is important in such analyses to take into consideration not merely the releases from the American nuclear industry, but instead to consider the sum total of uncontrolled and uncontained releases from nuclear facilities worldwide.

One way to reduce risks drastically from the handling of nuclear wastes would be to curtail their production. If the nuclear industry were closed down completely and all wastes were disposed of, handling risks would be reduced to zero. However, all projections are that the nuclear industry will proliferate, and that the quantity of wastes produced will increase. This will vastly increase the risks from handling wastes, particularly during the most vulnerable phase, that of transportation.

The second type of risk--that pertaining after the final, intended-permanent disposal of nuclear wastes--will remain for at least hundreds of thousands of years, even if the nuclear industry closed down tomorrow.

The basic features examined in risk analysis are the state of the technology, research and development practicalities, the time needed for implementation and operation, and general environmental knowledge (e.g., about the likelihood of earthquakes in a given disposal area). For the handling of wastes (still putting aside the human element), risk analysis is highly developed and reliable. For evaluating hazards after final disposal, however, risk analysis is an unproven tool. The difference lies in the time factor. In the short time spans (decades) needed for handling wastes, technologists and engineers can deploy various systems for tests, take account of feedback, and improve the technology as they handle the wastes. This is impossible (e.g., taking feedback into account) for the long periods of time (hundreds to hundreds of thousands of years) that permanent disposal is supposed to provide protection. As far as we now know, disposal in deep geological burial will provide permanent protection. Extremely low probabilities of certain types of failure and accidents can be assigned on theoretical grounds, but there is no body of experience on which to base these assignments. In actuarial terms, hazard indexes can be ascribed with some confidence to the risks of handling wastes, because we have a body of past experience to build on; insurance statisticians could assign no hazard index to the risks after final disposal, however, for we have no experience of their performance over the long periods of time required. Furthermore, our knowledge of long-term ion exchange, solubility of certain waste compositions, effects of wastes on various kinds of bedrock, and biological concentration of effluent wastes is limited. Despite all this, most people knowledgeable about final disposal methods believe that the hazards after final disposal are in fact extremely low, and that they are considerably less than the hazards from handling wastes.

This evaluation is not merely of theoretical interest. If hazards from handling wastes are indeed considerably greater than hazards after final disposal, this could lead to choices of technologies in which there is minimal handling and minimal time lapses between the production and final disposal of wastes. For example, separation, transmutation, and even fuel reprocessing might be bypassed for quick disposal if the hazards of handling were thought to be excessive.

2.10.2. Some Statistical Considerations in Risk Analysis

Crucial long-term hazards of radioactive materials are their somatic, carcinogenic, and genetic effects on human beings. Here, again, short-term somatic effects are fairly well understood. We have fair but not complete knowledge of carcinogenic effects from radiation. The linear hypothesis--that the risk of getting cancer is cumulatively proportional to the radiation dose, no matter how small--has much theoretical support, and is bolstered by the hypothesis that some proportion of cancer contracted by human beings (and other organisms) is caused by natural background radiation.

A basic difficulty in assigning, e.g., a cancer hazard index for nuclear wastes, is that these effects occur perhaps 15 to 45 years after exposure or ingestion, and the chain of causes is in most cases practically impossible to trace. Thus industry spokesmen can say that there have been no deaths from (read: there have been no deaths traced to) nuclear wastes, while opponents claim that the substantial increase of cancer since 1945 is the result of the dispersion of nuclear wastes (mostly from bombs) in the atmosphere. At present there is no scientifically unchallengeable way to substantiate either of these statements. As remarked above, however, the linear hypothesis seems sound, so that any increase in radiation probably gives some increase in cancer, as well as other somatic and genetic effects.

Such effects can be determined statistically, but they cannot be assigned to individuals. An individual can possibly determine the risk of living in any area by taking the combined manmade and natural background radiation as proportional to a rough hazard index.

Results of exposure are thus difficult to determine. Also, how possible effects are expressed makes a great difference. If possible cancer deaths, e.g., are distributed over the half-life of plutonium, they seem to be virtually insignificant. If all possible cancer deaths are given in a single figure, they seem to be overwhelming. Also, since no individuals can be specified, cancer deaths can be represented statistically as so many minutes of life lost by everyone, rather than as many years of life lost by a few individuals. The use of statistical measures in risk analysis, particularly with respect to long-term radiation effects, thus offers various ways of representing hazards.

It should be remarked that the health hazards discussed throughout this section (2.10) are primarily those that would be sustained only after failure or accident. Often, also, the hazards are presented in worst case form, that is, with the hypothesis that dispersal and dosage is universal and maximum. In fact, results of failure and accident would probably be less than most projections, since uniform dispersal and dosage is practically impossible.

2.10.3. Radiation Standards

Acceptable, permissible, allowable, practicable, etc. dosages of radiation are set by various standard-setting agencies for all facilities and operations in the nuclear program. Often this has been done using natural background radiation as a base. Natural background is not a good criterion because a) it has changed since 1945, b) it varies according to bedrock radioactivity, and c) it varies according to altitude. Also, given the linear hypothesis, background radiation is itself dangerous, and so should not be used as a standard with the implication that it is safe.

In a perfect containment system, the radiation reaching the human environment from wastes would be zero. In fact, some effluents do escape into the environment, and there would be exposure in case of failure or accident. One argument for deep geological burial is that chances of exposure then would be extremely small.

From a technological standpoint, standards should be used to design waste systems in such ways that failures or accidents will not result in dosages exceeding the standard. As for the standards themselves--again harking to the linear hypothesis--they should be set as low as is both safe and practical.

2.10.4. Qualitative Risk Analysis

All operating technological systems must be operated, maintained, supervised, or in some way guided by human beings. Thus, there is a human element or part in every technological system. Often in the consideration of technological systems, the human element is considered to be unproblematic, or it is ignored (as we have done in Section 2.10.1). However, it cannot be reiterated too many times that technological systems are not self-implementing. Human beings are the necessary motivators of technological systems. They are also the key elements in the systems.

Modern assembly-line division of labor techniques are designed to reduce the human element to machine-like precision. However, human beings cannot be relied on to perform consistently. In extraordinary situations where initiative and thought is required, human beings sometimes avert failure or accident, but in both extraordinary and in routine, repetitive situations, human beings also make errors. Human beings also can sabotage technological systems intentionally.

Precautions for routine errors can often be designed into a technological system. Redundancy to provide back-up for human parts and actions can be as effective as redundancy of mechanical parts. Despite this, there are many qualitative aspects of human behavior that cannot be anticipated. No one thought that a workman might use a candle around combustible wiring at Brown's Ferry, nor did anyone anticipate that after that workman had set the wiring afire once (without any dire consequences), he would continue to use the candle and a few days later set the wiring afire again (with almost disastrous consequences). No one can anticipate the factors of boredom, sleepiness, inattention, nonchalance, distraction, disdain, anger, enthusiasm, illness, insanity, and sudden death. A very basic defect of risk analysis of technological systems, then, is the inability to account for the qualitative aspects of the human parts of the system. A system that is otherwise technologically superb can be torpedoed by completely unimagined and bizarre, inadvertent or willful human error.

The conclusion is that risk analysis as a tool is strictly limited in two respects, a) it is not proven for long-term technological systems, and b) it cannot take into account the non-quantifiable, qualitative aspects of human behavior. Preference for final disposal systems that do not require human supervision, thus, rests on the desire to reduce uncertainties. When wastes are managed actively by human beings, we know that some errors will be made. If wastes are disposed of in a way meant to be permanent and unsupervised, we may be uncertain about the permanency, but at least we need not worry about managerial error after the wastes are emplaced.

2.11. Nuclear Waste Safeguards

All nuclear wastes now being produced are hazardous, but none are in forms that could be diverted easily for military or terrorist use. It would take extraordinary means, e.g., to extract enough plutonium from present wastes to make a bomb, or to disperse radioactive materials over a city in dosages fatal to its inhabitants. Also, the chances of a chain reaction occuring spontaneously in disposed wastes is extremely unlikely, and the results of such an event if it did occur would probably be small.

There is thus no great safeguards problem with existing wastes. The impact of the safeguards issue on the nuclear program as a whole does, however, suggest a basic criterion for waste treatment:

> Nuclear wastes should not be produced nor maintained in forms that can be used readily for military or terrorist purposes.

This requirement might be used, e.g., as an argument for reprocessing spent fuel, or for using plutonium as a fuel. Whatever technological adjustments it implies, the point is that the best safeguard for wastes is their uselessness for military or terrorist purposes.

2.12. The Coordination of Nuclear Waste Management with Other Hazardous Waste Programs

Other hazardous wastes are as dangerous and long-lived as nuclear wastes. Some of them are probably disposed of less safely than are nuclear wastes. In any event, all waste management technologies for hazardous wastes should be coordinated. We believe that extensive efforts to do this will be much more likely to increase the safe handling of non-radioactive waste, than decrease the safety of nuclear waste disposal.

3. FINDINGS ON THE POLITICS OF NUCLEAR WASTE MANAGEMENT

The key political notion is power. The basic political problem is to obtain, maintain, and participate in the distribution of influence. Without the political implementation of safe nuclear waste systems, there can be no safe nuclear program.

3.1. Introduction

The primary justification for political systems is that they provide protection for human beings. A political state provides security and stability that would not be available to individuals if anarchy pertained. Among the basic needs of society is energy for industry to produce goods. Most citizens and their elected representatives believe it is the government's responsibility to promote and regulate the availability of energy. In 1946, legislation was passed by the U.S. government enabling the Atomic Energy Commission to develop, promote, and regulate a commercial nuclear power industry. In 1975, development and promotion were transferred to the Energy Research and Development Administration, and regulation to the Nuclear Regulatory Commission.

The decision to proceed with the nuclear program was thus made 30 years ago. Since then, government and industry have invested billions of dollars and many professional and political careers in nuclear energy. The public has invested trust.

For more than 25 years, nuclear waste management was not politically prominent nor glamorous. Political hay was made in the fields of reactor developments and power production. Recently, however, critics of the nuclear program have publicized the technological fact that without adequate waste management systems no nuclear program is safe, and the political fact that so far no permanent disposal systems have been implemented. The basic political question concerning wastes in the larger nuclear debate, then, is:

Can safe nuclear waste management systems be implemented in the present political climate?

Probably the answer to this question is yes, but the situation is extremely complicated. Some LLW disposal programs have been implemented. But all attempts to implement permanent disposal systems for HLW and TRU have failed, in large part either because of lack of political support or because of political ineptitude. One major political error in the past has been the attempt of a secretive AEC to impose Federal decisions on State and local citizens without their participation in making those decisions.

Because waste management is technologically pivotal in building a safe nuclear industry, it has become pivotal--and glamorous--in the political arena. We have concluded that safe nuclear waste management is technologically most probably possible. The political issue is one of implementation. Proponents and some critics are working to bring various waste management systems to industrial scale. Some opponents of the nuclear program are trying to delay or halt development of waste management systems (whether or not they can be deployed safely) as one way to halt the development of a commercial nuclear power industry.

It is important to keep in mind that in this political context the technological facts are often not in dispute, and sometimes they are not even taken into consideration. Decisions turn not on whether something can be done, but on whether it is politically wise or expedient to do it. In the case of nuclear waste management, a nationally prominent politician might favor a waste disposal scheme because the American public as a whole wants nuclear energy, while local people might oppose it because they do not want a waste disposal facility in their backyard.

3.2. The Primacy of Politics in the Nuclear Waste Program

To the equal frustration of technologists who want to deploy waste management systems efficiently, and to industrialists who want to make profits from nuclear power production, the actual implementation of waste systems depends on the support and decisions of politicians. These political decisions about waste management do not necessarily--and sometimes necessarily do not--depend on technological and economic considerations. The commercial nuclear power program began as a politically motivated enterprise, and it remains such today. Political attitudes on a Federal level have remained consistently in favor of the nuclear program, in part because nuclear energy is symbolic of world power. This helps explain something that puzzles many critics; that is, despite the apparent low profits or even economic losses sustained by the nuclear industry over the years, the government still subsidizes the nuclear program and encourages the industry. Beyond this symbolism, however, the nuclear industry represents material political power, for besides providing electricity, it provides plutonium for bombs. Some kind of nuclear industry would be required for military purposes in any case. There are obviously great political advantages in having a primary program of Atoms for Peace, with military products as secondary byproducts.

As remarked above, as soon as waste was generally seen to be technologically pivotal, it became a point of political concern to both proponents and opponents of the nuclear program. It seems fair to say that no waste management program--no matter how efficient or even profitable--will succeed that does not have widespread Federal and local support.

3.3. Nuclear Wastes in Relation to Other Major Political Concerns

The public and politicians are not so concerned about nuclear wastes as they are about safeguards and reactor safety. Neither is the debate over the nuclear program itself so widespread and heated as that over general environmental pollution, overpopulation, and inflation. This reflects the general impression that the American public as a whole is in favor of a commercial nuclear power industry. Those who oppose the entire nuclear program usually do so from a political base that calls for other major changes in American society, such as a radical de-emphasis of consumerism and a general lowering of material standards of living. It is probable that most of the general public, even those who support moratoria on the development of the nuclear industry, do not reject the program, but merely want to be satisfied that it is safe.

As remarked in Section 3.2., continuation of the nuclear program is important to the United States in terms of world power and prestige. Most Americans are aware of this, and accept the political necessity of the program. For this reason, the great nuclear debate--while politically useful--appears to most people to have a foregone conclusion in favor of the program. The value of the debate, and the value of critics, is that publicity will assure that the safety of the program--and specifically of nuclear waste management--will be greater than it might otherwise have been.

3.4. Public Participation in Decisions About Nuclear Waste Management

Critics outside government and the nuclear industry were not the first to recognize the pivotal nature of waste--technologists have long known this--but critics were the first to make the question of safe disposal a major public and political issue. Much mistrust and disatisfaction with the nuclear program has come from the AEC's methods of maintaining secrecy and of imposing decisions from the Federal level. The AEC sustained two major political defeats in connection with nuclear waste management, the first when State and local forces successfully opposed the siting of a waste disposal facility in bedded salt at Lyons, Kansas, and the second when environmental critics caused the shelving of plans for the RSSF.

It is clear that numerous public forums must be made available for discussion of the nuclear program, and that specifically with relation to the siting of facilities such as for waste disposal, State and local governments and other organizations must be allowed to participate in making the decisions. Successful political decisions can be made only through widespread participation and distribution of decisionmaking power.

However, even in the best of circumstances, some groups will be poorly represented and others will disagree with the decisions. Large numbers of people in the world who have no voice in the decision will share the hazards and sustain some of the costs, but will derive few or no benefits. Some people do not want the hazards, costs, or even the benefits of the nuclear programs; others are indifferent, or ignorant of them. If the program is accepted and becomes routine, even the concerned public's participation will decrease. Finally, future generations cannot represent themselves. Although it is politically unrealistic to think that the interests of all these relatively powerless groups can count for much, in a matter as all-encompassing and long-range as the disposal of nuclear wastes, legislators still should attempt to take all people's needs and desires into consideration, even when these people do not or cannot represent themselves.

3.5. Political vs. Technological Time Scales in Nuclear Waste Management

The first prerequisite for any elected government official is to get elected, and then to get re-elected. In the United States, Representatives are elected every two years, Presidents every four years, and Senators every six years. In these circumstances, politicians generally must decide on issues with relation to expedient needs and current attitudes. Political decisions about long-term technological programs and systems such as for waste management, therefore, are often made on the basis of short-term needs and interests. The best that can be done in this situation is to try to keep everyone aware of it, and to urge that everyone take into consideration the long-term consequences of short-term decisions.

If politicians sometimes seem incapable of comprehending the long time-periods involved in managing nuclear wastes, technologists often do not seem to understand that legislative activities also take time. Standards must be set, regulations confirmed, and laws passed before the nuclear program can be fully implemented. Industrialists are well aware that licensing procedures sometimes take years. And the public is acquainted with the fact that enforcement of regulations also takes considerable time. It is not enough merely to have the technology, the investment, and political concurrence. Long lead times for legislation must also be taken into consideration.

3.5.1. The Political Impact of Future Generations

Future generations do not vote. It would be nice to leave this section with that single comment, but in fairness we must remark that the parents and grandparents of the next few future generations do vote. It is our impression, however, that concern for future generations plays little more than a rhetorical role in the politics of nuclear energy. Everyone expresses concern for future generations (Section 5), but few if any important political decisions are made on the basis of this concern. We believe that the operational attitude of most people with relation to future generations is that they can take care of themselves. And there is evidence for the political view that because no government has survived for more than a few centuries, the U.S. government is certainly not going to survive for thousands of years, so who cares? This sounds callous, but remember that this is a practical attitude in a political context. We must guard against this attitude in making decisions about nuclear waste disposal.

3.6. Public Distrust of Politics, Government, and Institutional Stability

The public distrusts government and industry in general for such reasons as Watergate and the General Electric scandals. With respect to waste management, AEC secrecy and avoidance of questions combined with condescending reassurance has made it neccessary for ERDA and NRC to be defensively open. There is great need for candor on the part of government in the great nuclear debate. This report is one attempt to meet that need.

Everyone is aware that the winds of politics can change direction radically and rapidly, that governments shifts, and that nations, empires, and civilizations rise and fall. For all these reasons, there is a great concern that permanent nuclear waste disposal does not depend on institutional stability. This is a political corollary of the technological observation that the human element is the weakest in any technological system. Honest answers and complete openness about the technological facts of waste management should eventually reassure most people about our knowledge of its safety. Deployment of systems that do not depend on human participation after final disposal should reassure most people that safety will not depend on unrealistic notions about institutional stability.

3.7. Public Opinions vs. Technological Facts

The hardest thing for technologists and industrialists to accept is that political decisons often are made not on the basis of technological facts or economic realities, but on the basis of what the public and politicians think is true, whether it is in fact true or not. Thus, if the public believes that a certain waste disposal system is unsafe, it may be decided against even though it is in fact safe.

Controversy among experts adds greatly to the public's confusion, and to the proliferation of the belief that no one in the nuclear program really knows what he is talking about. The result is general distrust of the safety of the nuclear program. In particular, the public is exposed to disagreements among scientists who are sometimes acrimoniously, diametrically opposed on such issues as hazards, technological uncertainties, methods of calculating risks, and the use of problematic data to make major decisions.

Most scientists, technologists, and industrialists do not have these doubts, or they have resolved them by the traditional methods of accepting the opinion of the majority of experts in specific fields as described above in Section 2.9. At least some politicians decide about specialized issues in this way, too, but it is politically dangerous for them to oppose the opinions of their constituencies. Consequently, a major need is for extensive public information and education about the nuclear program. Because the AEC tried to indoctrinate rather than to inform the public, it will take a while to gain public confidence. However, it is clear that without public understanding of and confidence in the technology and operation of the nuclear program, public decisions may be made contrary to technological facts.

It should be remarked that the public and politicians can be misled in either direction. Many people suspect that the AEC misrepresented the nuclear program as being safe, practical, and economic, when it is in fact unsafe, impractical, and uneconomic. Again, confidence can be gained only when there is disclosure of all facts and information, plus a forum where ERDA, NRC, and industry spokesmen answer questions openly.

Ours is a representative democracy, in which elected representatives make decisions for their constituencies. It is not so much that the people demand to make the decisions themselves as that they demand to participate in the decisionmaking process. They want to hear, and to be heard. If they understand they will usually go along with the decisions of their elected representatives, even if they disagree with them. If they disagree too much, they will vote their representatives out of office. With specific reference to the nuclear program, the greatest complaint we have heard from critics and the public is that the AEC eliminated them from any participation in the decisionmaking about the nuclear program. It seems obvious that decisions about such things as fuel reprocessing, the LMFBR, and waste management will not be made until the public and their elected representatives feel confident that they know what decisions to make.

3.8. Participation of Local Governments

The AEC appears to have paid insufficient attention to the fact that nuclear waste managment is under the jurisdiction of large numbers of overlapping regional, State, and local governments. HLW and TRU storage facilities today are operated by the Federal government, but several LLW facilities are operated by private industry under State jurisdiction. The experience at Lyons, Kansas, makes it particularly clear that all local organizations must be brought into the decisionmaking process.

Organizations for coordinating this participation already exists, such as the State Legislatures, the Western Interstate Nuclear Board, Councils of Governors, Trade Councils, Soil Conservation Districts (which often have jurisdiction over waste disposal), and so on. All these organizations must be dealt with in proliferating a nuclear industry throughout the nation, so serious efforts must be made to involve them in systematic and meaningful ways.

3.9. Responsibility for Nuclear Waste Management

Most people believe that the Federal government should be responsible for nuclear waste management for three reasons:

a. The government is responsible for protecting the health of citizens and the human environment.

b. The government is more stable and has more longevity than business corporations.

c. Waste management is only marginally profitable and the purpose of business corporation is to make a profit, not to protect the public.

The question arises as to what this responsibility entails concerning payment of costs for waste management. Do tax payers or rate payers pay the costs? And•are these costs paid at the time of the use of the energy whose production resulted in the wastes, or at the time of waste treatment and disposal, or are costs deferred to future generations? There are moral arguments that those who immediately benefit from the production of the wastes should pay costs, and economic arguments for deferring payment. It is not possible to predict which position will be politically viable at any time, although the prevailing view seems to be in favor of costs being shared through the tax base and the rate base by those--the Nation as a whole--who benefit from nuclear energy production.

3.10. American Capitalism, Free Enterprise, and Standards of Living

The American government has always promoted and subsidized business and industry. For the nuclear industry, this was begun with the AEC and is continuing with ERDA. At present, basic research and pilot plant development is still dominated by government, if for no other reason because government sets regulatory standards. Industry in fact complains that infirm government standard-setting practices curtail industrial research and development. However, because government is responsible for protecting the public, there seems to be no way of freeing the nuclear program from heavy government participation. Consequently, the industry will never be entirely subject to market pressures in a free enterprise system. All of this is to say that the impetus for the nuclear program is at least as much political as it is economic.

In effect, Americans have been voting for a nuclear program for 30 years. Most politicians believe that this vote is for a high-energy technological society in which high living standards can be maintained. Critics of the nuclear program often suggest that energy use could be decreased and that Americans could tolerate (or even benefit from) lower standards of living. There is, however, little evidence that the American people as a whole desire anything more than ever higher standards of living, which means continuation of present methods of utilizing energy (which are at least extravagant, if not wasteful) and growth of energy production. The upshot is that Americans are voting with their consumer habits for proliferation of the nuclear program.

3.11. Political Flexibility and the Need for Industrial Stability

A politician must remain flexible so that he can bend with the winds of current opinion when necessary. For this reason many decisions and even regulations are written in ways that are open to a wide variety of interpretations. This is sometimes quite frustrating to industrialists, who must depend on stability of purpose in making investments and building facilities. The only way to reconcile these diverse needs is for government and industry to work together to develop standards and technology. This is what has been done in the past, and in fact is the only way to proceed given that the political element sets the policy that technologists and industry must implement. That is, regulators must understand the technology for which they are setting standards, and technologists must understand the political policy that provides the basic goals for industrial development. This is another rationale for the joint nuclear program.

3.12. Forced Decisions and Decisionmaking Procedures

Decisions often must be made even in the face of technological, political, and economic uncertainty. Sometimes such decisions are made on the basis of what seems best according to past experience. However, systematic decisionmaking procedures lead to more uniformity in decisionmaking, and perhaps give better security than those based on hunches.

An obvious decisionmaking procedure is to assemble the opinions of those most knowledgeable about the technology, the public's needs and desires, and the economy, and then blast off. However, once such a decision is made, it still must attain political acceptability. When many uncertainties and differences of opinion are involved, there is endless ground for debate and delay. This is one reason--along with the fact that a decision has not so far been imperative--why no firm decision has been made on permanent nuclear waste disposal.

3.13. Irreversible Decisions and Self-Perpetuating Institutions

One reason for hesitation in making decisions about nuclear waste management is the realization that some modes of disposal would be irreversible. Dispersed wastes cannot be regathered, the decision to store HLW and TRU at Hanford in shallow burial tanks seems permanent because of the immense costs of moving the material now, and deep geological disposal would make wastes irretrievable without the most extraordinary efforts. Public and political unease about the nuclear program as a whole rests on the realization that any major commitment to a commercial nuclear power program might commit us to its maintenance whatever its hazards. It is probable that extensive proliferation of the nuclear power industry would be politically irreversible, if it is not already. The basic justification for this by proponents of the nuclear program is that given our imperative energy needs and the overall state of energy technology, nuclear power is the only viable alternative. The decision, most technologists, politicians, and industrialists say, is forced.

Despite the general belief that human institutions are not stable enough to last the hundreds and thousands of years that would be required if waste management systems were to be actively maintained, there is some worry that nuclear programs might perpetuate themselves beyond their need, e.g., after solar or fusion energy production made fission reactors obsolete. This is surely an academic worry. On the other hand, political and industrial establishments often try to maintain themselves and to oppose change. Thus, a fission reactor industry probably could not maintain itself after better energy sources were deployed, but it might be able--for a while--to delay the development of new energy sources. Some critics of the nuclear program say that this is what is happening today, and suggest that ERDA should be NERDA (for Nuclear Energy Research and Development Administration), because more than 90% of the budget goes for nuclear energy research as opposed to less than 10% for combined research on solar, improved fossil fuel, and fusion energy. Some political hesitations about the nuclear program stem from worry about putting all our energy eggs in the nuclear basket.

3.14. Autonomous Technology

We have said that political action is necessary for the implementation of technology. This view is opposed by the claim of some theorists that the development of technology is autonomous, and that the advance of technology (e.g., the development of means to generate higher and more concentrated forms of energy) is autonomous. Without taking a position in this debate, one can ask the question:

> Can a major technological innovation be curtailed, particularly if it is an energy-production technology with major military applications?

Politically, the answer must be that it is impossible to curtail such a technology.

Opponents of the nuclear program ask that we close up the nuclear shop completely. Putting aside arguments for maintaining a nuclear program for military purposes, it is highly improbable that politicians or industrialists would give up the nuclear program when many other nations are proceeding with it. Japan, for example, unlike the United States, probably does have little other option if it is to maintain a high-energy technological society. And it is wildly unrealistic to hope that politicians (or the general public) would forego a nuclear program when other nations are producing plutonium for bombs.

No major technology has ever been abandoned voluntarily. Poison gas in warfare was abandoned because it was inefficient and better methods were available and besides, research continued, gas was used in Vietnam, and many nations have stores of nerve gas, just in case. Certain kinds of research on recumbent DNA are not now done in the United States, but our scientists have access to the results of such research done in other nations. We do not do certain kinds of research on living human subjects, but the Nazis did. Calls to stop research on methods of invading privacy, or of influencing human beings psychologically, are voices in the wilderness. The image of Don Quixote on horseback tilting at windmills with a lance is--perhaps unfortunately--the perfect image for opponents of the commercial nuclear power program.

4. FINDINGS ON THE ECONOMICS OF NUCLEAR WASTE MANAGEMENT

The key economic notion is profit. The basic economic problem is to make a profit. Unless there is profit in nuclear waste management, there is no economic incentive to undertake it.

4.1. Introduction

Everyone agrees that viewed as an independent enterprise, nuclear waste management would be marginally profitable at best. More money is spent on HLW and TRU storage now than is returned for the service, and although private LLW management facilities are making a profit, it is not a business any corporation would go into without government support.

From the viewpoint of the entire nuclear fuel cycle, the back end including waste management is primarily an expense, although not a heavy one considering the profits or potential profits from energy production. In terms of proposed general benefits of great quantities of energy for society from the nuclear industry, the costs of waste management dwindle to near insignificance, being estimated, e.g., as not exceeding 0.06% of the rate base for electricity.

Nevertheless, there is considerable concern about who is to pay the costs of waste management. Should costs be centered on fuel reprocessors, who generate most of the wastes, and passed on by them to the rest of the industry in the cost of fuel, or should costs be more broadly based immediately: And should costs be paid at the time of the production of the wastes, or should they be extended so future benefactors of our having developed nuclear energy can pay some or all of them? And should government or industry bear the major costs?

Economic reality is that the users of nuclear energy--primarily the benefactors--will in one way or another bear the costs. Assuming that the nation as a whole benefits, many observers believe that the costs of waste management should be paid when produced or disposed of through some combination of general assessments on the rate base and tax base.

4.2. Economic Incentives and Subsidies

As remarked in Section 3, the nuclear program is promoted for political as much as for economic reasons. However, if there were not some ultimate promise of great and long-term profits, it is doubtful that the nuclear industry could be sustained. For comparison, the space program cost a great deal and generated profits within the space industry, but no large, profitable, private industry developed out of it, so the space program as such has lost support. In another arena, whether or not the Vietnamese war was pursued for profits, American business and industry definitely began to turn against it when it became apparent that the war was becoming an economic disaster.

All indications are that at present no great profits are being made by the nuclear power industry. However, the promise of profit is immense. No major energy corporation can afford not to invest, even if it means current losses of hundreds of millions of dollars. If the industry proliferates as projected, profits from it will exceed those from any venture previously known.

Even if waste management is merely a necessary service that must be paid for, it can still (of course) make a profit for those who build, maintain, and manage the facilities. One hypothesis about the present stalemate in the deployment of waste facilities is that government and industry are jockeying to see who pays the major costs. Industry would prefer that major costs come from the tax base (so government pays), whereas government would prefer that they come from the rate base (so industry pays). This juggling may appear academic to energy users or the American public, for in either case they pay eventually. But of course politicians would like to reduce taxes, and industrialists would like to reduce rates. Most probably the program will continue with the industry heavily subsidized by government.

4.3. Property and Control

Critics often seem to think that current economic losses or marginal profits will or should lead industry to stop investing in the nuclear power program. However, besides the promise of great future profits, there is great economic value in the mere existence or possession of the industry itself--its physical facilities, political connections, and personnel. Even with the industry merely breaking even, or even operating at a slight loss, it would support hundreds of thousands of workers and would provide needed energy. No institution as large as the nuclear industry is ever abandoned merely because it shows no conventional profits. (On the other hand, the space industry was at least broken up; it did not, however, provide something obviously useful, such as energy.)

Another economic advantage of a large nuclear industry is control, not merely of energy services in a region, but again of the economy that underlies a large number of transactions in society. For comparison, consider a group of people who continue to run a large newspaper at a loss. The profits gained from controlling a large energy industry--like those from running a newspaper--do not always show up simply or conventionally on the profit/loss ledger.

4.4. Responsibility, Risk Avoidance, and Bankruptcy

A top energy corporation executive says, "If you think we are in business to produce energy or provide services, you're wrong; our business is to make profits for our stockholders." Most industry spokesmen insist that they have no responsibility for the protection of the public other than to follow the standards and regulations set by government. If industry follows the rules and something terrible happens, government, not industry is responsible. And like many technologists, many industrialists say that they make no moral judgments. The insist that it is not their business to decide about morality or quality, nor about the use of the energy they produce. In a major study of power company decisionmaking (Values in the Electric Power Industry, Notre Dame Press, 1977), K. M. Sayre reports:

> The suggestion that at some stage it might be appropriate to evaluate the implications of the use of the Company's product in environmentally harmful industry (automobiles and heavy appliances with "planned obsolescence" mentioned as putative examples) was declined so forcefully that we deemed it counterproductive ever to breach the topic again.

The responsibility of industry is to make a profit.

For this reason, the mere avoidance of risk is inadequate incentive for industry action. Incentives must be in the form of positive profits. It is impractical to expect industry to avoid risks if it means loss of profits. On the other hand, no industry will subject its customers to risks that might mean extensive loss of business. This might be reassuring in waste management if the hazards were immediate. However, because hazards from failure or accident are most likely to bear on future generations, some people worry that corporate executives concerned with present profits may not be too careful.

Finally, unease derives from the fact that a corporation can declare bankruptcy and thus pull out of any commitments. This might be disastrous at a waste management facility, and would impose a heavy financial burden on government which would have to take over. This possibility provides another argument for Federal management in the first place.

4.5. Growth, American Capitalism, and Standards of Living

The American economic system is predicated on growth. Profits are increased by increasing production, turnover, and consumption. Most American industries are geared to growth. Projections of future energy needs call for ever larger increases. The nuclear industry itself is expected to increase from the present 59 reactors to 200 to 500 by the year 2000. Some promoters speak of 1000 reactors in the United States by 2025. With such an increase, the production of wastes would increase greatly also. The waste management program then might be large enough to attract the attention of fairly large profit makers.

It is doubtful that American capitalism as we know it can survive without growth. Although there are good arguments for maintaining economic equilibrium, most people in power are committed to the growth systems, so growth will doubtlessly increase as long as some radical change or disaster does not overtake the economy.

As remarked in several sections above, Americans seem to want growth to increase their standards of living. The maxim that Americans will not tolerate lowered standards of living, but always desire to have them increased, is gospel for American businessmen.

4.6. Cost-Benefit Analysis

Cost-benefit analysis is required by law for most government projects, and it is a method used by most industrial corporations to evaluate programs. As discussed in Section 2.10.1., cost-benefit analysis is useful when all parameters being considered are comparable in the same metric, usually dollars. In crudest economic terms, then, industry's question is:

> How much is government and the public willing to pay for nuclear waste management? That is, how much profit can be made from protecting the public for the government?

Cost-benefit analysis is attacked from many sides as being inadequate for the evaluation of overall societal problems. Many things--a sense of well-being, aesthetic pleasures, security--cannot, it is claimed, be measured in dollars. It is not just that it is difficult to assign dollar values to these things; the point is that they do not belong in the category of things to which dollar values are appropriately assigned. Consequently, they cannot be compared with items that are amenable to the dollar metric of cost-benefit analysis.

Such claims about qualitative vs. quantitative values are usually met by businessmen with the cynical comment: Everything has its price. Obviously, they say, peace and quiet and privacy, e.g., have dollar values, because people are willing to pay plenty for them. Aesthetic pleasures do not come cheap, because even if a museum is free, e.g., somebody pays for the paintings. And so on. In opposition to those who say qualitative things are not considered in cost-benefit analysis, businessmen either point to the high costs of some qualitative things, or they say that qualitative matters have been considered and dismissed because nobody thinks enough of them to be willing to pay for them.

The economic conclusion is that people in fact do get what they are willing to pay for. There is no free lunch. Very high quality waste management is available, at a price.

5. FINDINGS ON THE MORALITY OF NUCLEAR WASTE MANAGEMENT

The key moral notion is equity. The moral problem is to distribute risks, costs, and benefits equitably. This is difficult in nuclear waste management, because at present the risks extend to everyone present and future, the costs usually extend wider than the benefits, and substantial benefits are enjoyed only by a minority of the world's population.

5.1. Introduction

The equitable distribution of risks, costs, and benefits is a moral ideal subscribed to by almost everyone in some form or another. Its realization in the world as we know it, however, is virtually impossible. At the present level of world energy production and technological development, the materials we can utilize as resources are relatively scarce, and the result is a world of limited goods. That is, current production of goods and commodities is obviously not enough to satisfy everyone's desires, and there are reasonable estimates that if this production were equitably distributed, everyone would be malnourished and ill clothed and ill housed. There are challenges to this conclusion, but when one considers that even if everyone's needs could be satisifed with current production, the existing political and economic systems--both socialist and capitalist--either contain no mechanisms for equitable distribution, or actively oppose it. Thus, even if the material facilities for distribution existed (and they do not, which is another problem), equitable distribution of food and goods would require worldwide revolution.

Most people who subscribe rhetorically to the principle of equity seem to understand its implications, which leads government, industry, and the general public not to take it very seriously. On the other hand, some radical critics believe that equity is more important than the status quo, and that political and economic revolution is needed to provide everyone with the necessities of life.

Proponents of the commercial nuclear power industry say in turn that the way to reach a fair distribution of the necessities of life--although admittedly not an equitable distribution of all goods--is by increasing the quantity of energy for the production of commodities until there is such a surplus beyond bare needs that no one must go in want of adequate food and shelter. Although it appears today as though risks and costs are unfairly distributed over people who do not benefit from the nuclear program, in fact, the argument goes, the entire human race--present and future--is the benefactor of the proliferation of nuclear power. If equitable distribution of the basic necessities of life is at issue (and it seems insanely utopian to argue for equitable distribution of everything), then growth of energy production is a way to do it that does not require total revolution, but follows from established political, economic, and industrial institutions. With respect to the situation in the United States, this is a version of the Invisible Hand thesis, the view that market competition in a free enterprise system (subsidized and regulated by government) will automatically benefit the whole society.

The conclusion concerning nuclear waste management is that risks and costs appropriately pertain to everyone now, and that everyone will benefit eventually.

5.2 Participation

The greatest moral outrage expressed by critics of the nuclear program, and by State and local governments and the general public is that the Federal government--specifically through the instrumentality of the AEC--has made innumerable decisions concerning the development and siting of nuclear facilities without the effective participation of the people whose lives will be affected. Strictly speaking, these decisions have been legal, and they follow from the procedures of representative democracy in which elected representatives establish agencies (here the AEC) and appoint officials to carry out specified programs. To the extent that elected representatives have gone along with the AEC, the American people have participated in AEC decisions.

Nevertheless, the AEC was secretive, and at the very least clumsy in its political relations with local governments and the public. With the passing of the Freedom of Information Act, ERDA and the NRC are required by law to be open, and they have learned from the AEC's mistakes about the necessity of widespread participation.

Most Americans believe that they have a right to make decisions for themselves. Once they participate in decisionmaking about the development and siting of nuclear facilities--particularly in touchy waste management matters--a considerable amount of the present moral outrage will probably diminish.

There is a further matter that must be remarked on in this context. These findings are ordered in a hierarchical sequence. Without waste management technology, there is no program; without political cooperation, there is no implementation; without profits, there is no investment; finally, unless the details of technology, politics, and economics are ironed out, there is no (operationally meaningful) place for morality. But morality is not entirely toothless. What we have described here as moral outrage at being excluded from participation has roots not merely in the abstract principle of equity, but also in considerations of self-interest. Particularly in areas where nuclear facilities are sited, local people want their fingers in the pie. This comment will seem unduly cynical only to those who are automatically pious when morality is mentioned; the point is that in facility development and siting, what is there to be distributed--equitably or not--is a lot of influence and profit. Local people think in terms of local politics, jobs, and resource commitment. It is an important principle of American morality to look out for one's own self-interest. In this way, the moral demand for participation is good business.

5.3. Representation

All governments face the difficult problem of justifying actions that result in circumstances some people do not want. Most Americans do not want the risks and costs of the nuclear program, but they accept them because of the benefits. Some Americans do not want even the benefits. Whether they really do not want any benefits of a high-energy technological society, or whether they believe that the benefits are not worth the risks and costs (i.e., that the entire program does not result in net benefits), their course is set if they continue to participate in the American political system. That is, until they can convince the majority of their views, they must accept the decisions made for them.

A much more difficult problem is that of justifying actions which affect people who have no legal right to participate in the decision. The decisions of the industrialized nations for the past 300 years, and the decisions of America today, have profound effects on the course of other nations and the future of all mankind. Many critics say that the American people--a minority--does not have the right to make such far-reaching decisions for the majority of people in the world.

As in Section 5.2 we reported a connection between morality and economics, now we report a connection between morality and politics. Most Americans believe that to some extent the possession of power implies moral right. This connection may be supported by a work ethic, i.e., the view that Americans have worked for and so deserve their power, but whether supported or not, it is a fact of American society. It is not exactly the view that might makes right, but rather it is the view that in the big picture God or the system rewards the deserving. Of course this attitude is by no means new. People of great power have always believed that they know best. Consequently, in their position of superiority, the powers-that-be do believe that they have the moral right to choose for mankind. Most of America's leaders evidently subscribe to the view described in Section 5.1, that the nuclear program is good for all mankind.

5.4. Future Generations

Of great rhetorical concern--although, as we have already remarked, evidently not of much operational influence--is the question of the rights of future generations:

What is our moral responsibility concerning future generations?

Critics of the nuclear program, particularly in consideration of the waste problem, say that we should not do things that will limit the options of future generations. For example, the nuclear program may commit future generations to nuclear energy (because it would be impossible to change the system without dismantling the entire economy), to institutions they might rather not have (such as a nuclear safeguards secret police), or to risks and costs of waste management even if the commercial nuclear power industry failed or were superceded.

As already remarked, proponents insist that future generations will thank us for developing nuclear energy, particularly since we have already precluded their options by using up most of the fossil fuels. Opponents say that we have neither the right nor the ability to decide what future generations will value.

Although it is safe to predict that future generations will value security, shelter, and food--and if recent history is any indication, they will also value high-energy technological civilization--the statement that we cannot know what they will value leads to a kind of moral argument in favor of going ahead with the nuclear program. That is, we do desire high-energy sources, and so far at least Americans have accepted (or have not yet rejected, depending on how you view the initial and present decisions) the nuclear program. We should minimize the impact on future generations, but it is impossible to reduce that impact to zero. Whatever we do, we limit and shape future possibilities. And whatever we do, we cannot commit future generations, because they will make their own choices. They might decide, for example, to leave HLW and TRU in shallow burial at Hanford, and take the consequences. We cannot even commit them to knowing what we have done. A new Dark Ages might descend so that the people of the future would not even understand why a certain area in eastern Washington is hazardous to health.

Given all this, and given the responsibilities we have for our own welfare and the welfare of other people now living, moral wisdom seems to be to do best for the living, without overt concern for the not-yet-born. This is certainly the attitude of leaders of those underdeveloped nations who are promoting industrialization and resource development while giving conservation a very low priority. Is it moral to conserve for the future when living people are unclothed and starving?

Whatever the moral rationalizations, there is clear indication in present actions that where present government and industry might suffer costs from assuring benefits to future generations, future generations will have to take their chances. Whatever the rhetoric, it is impractical to expect people today to take risks or to forego benefits for the benefit of future generations.

5.5. Lying

Dipolmacy--or management--is, it has been said, the art of lying. Anyone who has had any administrative responsibility knows what is meant by that epigram. With respect to the nuclear program, many critics believe that AEC officials lied over the years about risks, costs, and benefits. The Federal government is rather sensitive about that sort of thing these days, and the current phrase that complements the Freedom of Information Act is the admonition to do one's business in a fish bowl. However impractical this advice may be, administrators should remember that most Americans think lying is wrong, and that lies--even on the highest levels of government and industry--will come out. (However, lies do not always expose themselves, which is a reason to insist on the widest possible participation.)

5.6. The Statistical Man

One way critics and the public view proponents of the nuclear program as lying is through the use of the statistical man. That is, many people are outraged rather than reassured to be told that in some worst possible case of accident to a waste facility, the number of additional deaths incurred would be merely 0.4 a year averaged out over 20 half-lives (480,000 years) of plutonium (the time it takes to decay to harmlessness), or that the great benefits of the program will cost only 17 minutes from everyone's lifetime. Everyone knows that real people die at specific times, and that no one loses 17 minutes, but that given individuals lose years by dying early.

5.7. Advertising and Promotion

It is not necessary to go into the ways that advertising and promotion literature can appear to be dishonest. Everyone concerned remembers the AEC's statement that nuclear energy would be so cheap that no one would need meters. As throughout this section (5.), the basic message is that the American people are concerned as much--and sometimes perhaps more--to understand and to participate in making the decisions about what is being done (particularly about what is being done to them), as they are about what is done.

5.8. Quantity vs. Quality

Our research converges on the observation that technological circumstances lead Americans (and all industrialized peoples) to the very strong feeling that only what is quantifiable is real, and that economic needs lead them to the belief that only what has a monetary price is valuable. The American government asks for cost-benefit analyses of all programs. We must conclude that unless moral considerations can be priced and quantified, they will be--and are--superceded by technological, political, and economic imperatives.

5.9. Responsibility

Moral responsibility can in fact pertain only to individual human beings. Governments and industries and other institutions have legal rights and responsibilities, but these non-human entities cannot be held morally responsible. If only human beings can be morally responsible, then moral blame cannot be put off on the government or the corporation. Most people understand this, but government leaders and corporate executives are often not held completely responsible morally for things they do in the name of the company. Often there is a conflict, for it is sometimes thought moral to do what is legal for the institution, although that action might be immoral if performed only for and in the name of an individual person. Company business may even forbid conventionally moral action. In the report on power company decisionmaking already quoted (Section 4.4.), K. M. Sayre remarks that:

> The hypothetical "altruistic" executive who ranks other concerns ahead of his corporation's self-interest is not praiseworthy by any internal standards; rather he is a bad decision-maker who must be promptly replaced.

In our interviews and reading we have found mixed attitudes about this very complex moral situation. Many people see it as a dilemma, and it obviously cause conflicts of loyalties. Some employees of the nuclear industry have resigned to express their personal moral disagreement with industry practices. On the other hand, major figures in science and government have promoted the nuclear program from profound moral convictions that it is good for mankind. We conclude from these observations that despite our ranking of moral incentives below those of technology, politics, and economics, it is possible that major decisions about the nuclear program may be determined by moral (and by this we mean also religious) considerations.

5.10. Technology and Morality

It is stressed herein that technological systems must be implemented by human beings. And some people think all technological advance is good. But because the use of technology can be dangerous and harmful, we must evalaute all technological innovations. Always remember that just as technological systems ae not self-impelementing, so also:

> Technological systems are not self-evaluating.

6. FINDINGS ON THE AESTHETICS OF NUCLEAR WASTE MANAGEMENT

The key aesthetic notion is taste. The aesthetic problem is to attain satisfaction. Who has a taste for nuclear waste?

6.1. Discussion

A considerable portion of matters designated as qualitative are aesthetic. People are permitted to satisfy their tastes--they are indulged--as long as no one is hurt, or as long as the indulgence is paid for. That is, what in itself is said to be incapable of measure in monetary terms can, nevertheless, be priced by those who have the power to permit or forbid it. That is, it is perfectly obvious that not these things in themselves, but their availability can be and is priced, and that a lot of us are willing to pay plenty for them.

Tastes are notoriously various, and obviously actions to satisfy contrary tastes often conflict. It has been suggested seriously that nuclear waste be placed in areas protected under the Wilderness Act, because very few people enter the wilderness and thus few are likely to be harmed by any radioactivity there. Hearings on the siting of nuclear facilities always feature confrontations between people who would like their village to remain small, or their seacoast natural, with people who are excited at the prospect of growth and industrial development.

From an aesthetic viewpoint, the great nuclear debate concerns the tastes for different styles of life of different groups or types of people. Some opponents of the nuclear program would prefer a low-energy world in which peace and quiet were not disrupted by large industries. Proponents obviously prefer the complexity and excitement of high-energy society. It is important to recognize that this disagreement over ways of life is not to be reconciled by pointing to one or the other as best for mankind. Presumably mankind could prosper in either situation, but even if one way is better than the other in some sense, it is unlikely that whoever has a taste for the one will ever be convinced that the other is preferable.

7. FINDINGS ON THE GENERAL SOCIETAL IMPACT OF NUCLEAR WASTE MANAGEMENT

The key societal notion is survival. The primary problem of any society is to survive. The question, then, is: Are nuclear wastes a threat to the survival of society?

7.1. Introduction

Technological, political, economic, moral, and aesthetic concerns are all parts of the societal complex. All of our findings are about society. Supposing that external security is assured--and were our concern with the entire nuclear program, we would have to say more about external security here--the basic societal problem is to assure harmonious interaction among internal elements. We have already indicated some of the liasons and adjustments among basic institutions. It appears that to the extent that the nuclear program is important in a society, nuclear waste management becomes pivotal. Thus, opponents and proponents alike believe that the decision about wastes will have a profound effect upon the course of American (and western and world) society.

7.2. Nuclear Waste Management in the Societal System

The organization of this report makes it abundantly clear that the waste problem is not merely technological, but that the technological system openly intersects with many other systems. Technological solutions not only must be politically acceptable, but also they must be economic. Technologists, and even industrialists, sometimes wonder why people do not leave them alone so they can go ahead with nuclear waste management (or they wonder why the government does not hurry up and pay them to do it). The answer--documented above--is that the decision about wastes is a decision about the nuclear program which in turn is a decision about the future course of our society. A lot of people want to be in on that decision.

7.3. Institutionalized Positions

From an overall societal viewpoint, all positions taken by individuals from institutional viewpoints must be scrutinized carefully for bias. Obviously everyone is a general representative of society, but most of us are affiliated with specialized institutions that influence our preferences and beliefs. It is not surprising to find technologists saying that nuclear wastes can be disposed of safely, nuclear physicists suggesting that there may be undiscovered uses for the wastes, industrialists advocating reactor proliferation to meet growing energy needs, environmentalists suggesting moratoria, politicians worrying about safety, college professors asking for more time, moralists preaching doom, and regulators proposing more studies and reports like this one. Hard-line opponents of the nuclear program can accept no waste system as safe, and totally committed proponents must accept some system as safe. It is not that an institutionalized position is automatically wrong, for in fact some or many of them are probably largely correct. It is just that from an overall societal viewpoint, the waste problem cannot be solved by specialists. That is why--given some viable technological alternatives--the final decisions will doubtless be made by generalists, i.e., the elected representatives of the people.

7.4. The World System

American society is part of a much larger societal system, first of the industrialized West, and then of the entire world. The majority of people in the world do not live in industrialized society. It is debatable whether or not most people want to live in a high-energy technological society. In any event, it is clear that those who have the technological knowledge, political power, and industrial capacity to do it have made the moral and aesthetic decision to proceed with a nuclear program with the intent of uniting world society in one high-energy civilization. Our investigations show that those who are in the best position to know believe that the resulting nuclear wastes can be disposed of safely.

II. PROPOSED GOALS FOR THE REGULATION OF NUCLEAR WASTE MANAGEMENT

8. NUCLEAR WASTE MANAGEMENT FROM A REGULATORY VIEWPOINT

The key regulatory notion is adequacy. Regulations must adequately coordinate technological, political, economic, moral, aesthetic, and general societal capacities and needs. Concerning nuclear waste mangement, the main regulatory question is: Are these regulations adequate to protection the public from the hazards of nuclear wastes?

8.1. Introduction

These proposed goals for the regulation of nuclear waste management are based on the Findings. Like the Findings, the Goals are tentative, and are subject to revision or rejection and replacement, and some will not apply to all wastes.

Most technologists, industrialists, elected representatives, and citizens appear to be in favor of the nuclear program. Thus we assume that the nuclear industry will proliferate as described in the Findings, and that the problem of regulating nuclear waste management is therefore critical. We believe that the societal coordination of nuclear waste management will be facilitied by the implementation of the following regulatory goals.

9. PROPOSED TECHNOLOGICAL GOALS FOR NUCLEAR MANAGEMENT

The primary technological goal for the regulation of nuclear wastes is:

> Adequate technological means of isolating nuclear wastes shall be assured that are physically safe and societally acceptable, for the purpose of furthering the nuclear program.

9.1. A new set of definitions of nuclear wastes shall be established that categorizes them strictly according to type, degree, and half-life of the radioactive nuclides involved, without respect to origin.

9.2. Nuclear wastes shall be contained from production through final disposal in ways that protect the public and the human environment.

9.3. Wherever possible, the human element shall be minimized in nuclear waste management.

9.4. After final disposal, containment of nuclear wastes shall depend on their composition, form, container, and physical environment, but shall be independent of and isolated from human maintenance and the societal environment.

9.5. All nuclear wastes (including gases) shall be reduced to or contained in solid form (or equivalent).

9.6. All nuclear waste systems shall be redundant for monitoring and for containment in case of failure or accident.

9.7. Nuclear waste dispersal in the atmosphere and the ocean shall be minimized.

9.8. A variety of nuclear waste disposal systems shall be developed and deployed, i.e., the nuclear waste program shall not depend on only one system.

9.9. Research and development of nuclear waste technology shall be undertaken with consideration of the requirements of deployment on an industrial scale both in spatial and temporal dimensions.

9.10. Nuclear waste systems shall be based entirely on existing technology, i.e., no system shall be allowable that depends on anticipated future technological developments.

9.11. Nuclear wastes in all phases of handling from collection, treatment, storage, transportation, to disposal shall be retrievable, i.e., easily accessible; after final disposal, nuclear wastes shall not be retrievable, i.e., they shall be totally inaccessible or accessible only by the most extraordinary means.

9.12. Absolutely certain demonstrations or proofs of the fail-safe nature of nuclear waste systems shall not be required; instead, very high probabilities of successful performance shall be required.

9.13. Claims about nuclear waste systems shall be evaluated by panels of experts in the field in cooperation with elected representatives of the public.

9.14. Risk analyses of nuclear waste systems shall be performed and described clearly to show the quantitative, statistical, and qualitative bases on which they are made.

9.15. Nuclear wastes shall neither be produced nor treated to result in forms that can be used readily for military or terrorist purposes.

9.16. Nuclear waste management shall be coordinated with other hazardous waste programs.

9.17. Nuclear waste systems shall be designed to maximize the possibilities of error, failure, and accident detection and correction.

9.18. In all nuclear waste system research and development, the worldwide nuclear waste situation shall be taken into consideration.

9.19. Nuclear waste systems shall conform to radiation standards set by all authorized agencies.

9.20. Nuclear waste systems shall be designed to minimize both the possibilities of and the consequences from failure and accident.

9.21. The time between production and final disposal of nuclear wastes shall be optimized to balance the hazards of handling before short-lived nuclides decay with the hazards of storage.

9.22. No nuclear waste system shall be deployed that absolutely forecloses modification or substitution of an alternative system.

9.23. All long-term nuclear waste storage facilities shall be designed so that their abandonment results in a situation that fulfills all requirements for final disposal.

9.24. Nuclear waste systems shall be independent of the rest of the fuel cycle in the sense that they do not depend on any but waste facilities for operation, but otherwise they shall be integrated with the rest of the fuel cycle.

9.25. Techniques for managing existing nuclear wastes shall neither necessarily be dependent on or provide a model for managing future nuclear wastes.

9.26. All nuclear waste management programs shall include plans and existing equipment for containment action in case of failure or accident.

9.27. Even after final disposal, nuclear wastes shall be systematically monitored, and plans shall be made for action in case of failure or accident.

10. PROPOSED POLITICAL GOALS FOR NUCLEAR WASTE MANAGEMENT

The primary political goal for the regulation of nuclear waste management is:

> Adequate political means of making physically and societally acceptable decisions for managing nuclear wastes safely shall be assured.

10.1 All public forums, from the elected bodies in Congress through local governments and voluntary organizations shall be effectively involved in the decisionmaking process about nuclear waste management.

10.2. Political expediency shall not override technological necessity.

10.3. Consideration shall be given to unrepresented peoples, both now living and not yet born, in making decisions about nuclear waste management.

10.4. No nuclear waste system shall be permitted that depends for safety on the permanence or stability of human institutions such as governments.

10.5. Complete information about nuclear waste management systems, facilities, operations, and decisions shall be openly available to the public.

10.6. Responsibility for nuclear waste management shall rest with the Federal government.

10.7. Worldwide cooperation on nuclear waste management shall be sought.

10.8. Stable standards for nuclear waste management shall be sought for the purpose of facilitating industrial development and deployment.

10.9. Political decisions shall not be permitted to foreclose all but one technological option, nor to perpetuate nuclear waste management programs or institutions beyond their usefulness.

10.10 Political decisions about nuclear waste management shall not be permitted to imperil civil liberties.

10.11 Political decisions about nuclear waste management shall not be deferred to future assemblies.

11. PROPOSED ECONOMIC GOALS FOR NUCLEAR WASTE MANAGEMENT

The primary economic goal for the regulation of nuclear waste management is:

> Adequate economic incentives shall be provided to assure safe management of nuclear wastes.

11.1. Costs of nuclear waste management shall be borne by the primary benefactors, i.e., the nation as a whole, of nuclear energy.

11.2. Where nuclear waste management is not conventionally profitable, the Federal government shall subsidize it.

11.3. In case of bankruptcy of a private nuclear waste management corporation, the Federal government shall take it over.

11.4. The Federal government shall be the owner of nuclear wastes at the point of their delivery to a disposal facility, whether or not that facility is privately or federally owned or operated.

11.5. Cost-benefit analyses of nuclear waste systems shall be performed and described clearly to show the quantitative, statistical, and qualitative bases on which they are made.

11.6. Economic motives shall not be allowed to override safety necessities in the choice of nuclear waste systems or in the timing of their implementation.

11.7. Nuclear waste systems shall, whenever possible, not foreclose other economic uses of land or resources.

11.8. The nuclear waste management program shall be economically independent of, but economically integrated with, the rest of the nuclear program.

12. PROPOSED MORAL GOALS FOR NUCLEAR WASTE MANAGEMENT

The primary moral goal for the regulation of nuclear waste management is:

> Adequate account of moral values shall be taken into consideration in making decisions about nuclear waste management.

12.1. Those who are affected by decisions about nuclear waste management shall have representation and shall participate effectively in the decisionmaking.

12.2. The interest of future generations shall be taken into consideration in making decisions about nuclear waste management, and so far as possible their options shall not be foreclosed.

12.3. The public shall be told the truth about nuclear waste management systems and decisions.

12.4. In risk analyses and cost-benefit analyses, clear consideration shall be given to moral values.

12.5. The ultimate moral responsiblity for nuclear waste management shall lie with the public; proximate moral responsibility shall lie with the elected and appointed officials who decide about and manage the systems, and with technologists and industrialists who develop and operate them; that is, everyone who benefits from or participates in nuclear waste management is morally responsible for its safety.

12.6. Existing benefactors shall be responsible for disposing of nuclear wastes from energy produced for their benefit.

13. PROPOSED AESTHETIC GOALS FOR NUCLEAR WASTE MANAGEMENT

The primary aesthetic goal for the regulation of nuclear waste management is:

> Adequate account of aesthetic values shall be taken into consideration in making decisions about nuclear waste management.

13.1. In risk analyses and cost-benefit analyses, clear consideration shall be given to aesthetic values.

13.2. Whenever other considerations are equal, nuclear waste management systems shall be chosen to provide a variety of aesthetic situations, e.g., ways of life, rather than to impose a monolithic aesthetic situation.

14. PROPOSED GENERAL SOCIETAL GOALS FOR NUCLEAR WASTE MANAGEMENT

The primary societal goal for the regulation of nuclear waste management is:

> Adequate societal integration shall not be disrupted by nuclear waste management.

14.1 No one institutionalized position--technological, political, economic, etc.-shall be dominant in making decisions about nuclear waste management.

14.2 Nuclear waste management shall be integrated in the local, regional, national, and world societal systems.

14.3 The safety of nuclear wastes after final disposal shall not depend on the permanence or stability of any societal system.

14.4 Nuclear waste management systems shall be designed so that they interfere only a minimal amount with other societal systems.

14.5 What we do with nuclear wastes shall be documented as permanently as we know how for the information of future generations.

14.6 In risk analyses and cost-benefit analyses, clear consideration shall be given to general societal values.