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Assessing Social and Economic Effects of Perceived Risk: Workshop Summary

Draft

S. M. Nealey
E. B. Liebow, Editors

March 1988

Prepared by
Battelle Human Affairs Research Centers
for Pacific Northwest Laboratory
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for the U.S. Department of Energy

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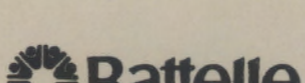

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ASSESSING SOCIAL AND ECONOMIC EFFECTS OF PERCEIVED RISK: WORKSHOP SUMMARY

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Richland, Washington 99352

SUMMARY

On August 6, 1987, the U.S. Department of Energy sponsored a one-day workshop at the Battelle Seattle Research Center, assembling a panel of experts from a variety of disciplines to discuss the complex dimensions of risk judgment formation and the assessment of social and economic effects of risk perceptions related to the permanent underground storage of highly radioactive waste from commercial nuclear power plants. Affected parties have publicly expressed concerns about potentially significant risk-related effects of this approach to waste management. To gain a better understanding of the impact assessment issues raised by these expressions of concern, DOE has undertaken a variety of activities leading up to the August workshop documented in this volume. A selective review of relevant literature in psychology, decision analysis, economics, sociology, and anthropology was completed, along with an examination of decision analysis techniques that might assist in developing suitable responses to public risk-related concerns. The workshop, "Assessing Social and Economic Effects of Perceived Risk," was then organized as a forum in which a set of distinguished experts could exchange ideas and observations about the problems of characterizing the effects of risk judgments. Out of the exchange emerged eight sets of issues or themes:

1. Problems with probabilistic risk assessment techniques are evident
2. Differences exist in the way experts and laypersons view risk, and this leads to higher levels of public concern than experts feel are justified
3. Experts, risk managers, and decision-makers sometimes err in assessing risk and in dealing with the public
4. Credibility and trust are important contributing factors in the formation of risk judgments
5. Social and economic consequences of perceived risk should be properly anticipated
6. Improvements can be made in informing the public about risk
7. The role of the public in risk assessment, risk management and decisions about risk should be reconsidered
8. Mitigation and compensation are central to resolving conflicts arising from divergent risk judgments

There was reasonable consensus among workshop attendees on two points: 1) perception of risk from a repository could cause social and economic impacts and therefore deserves further study; and 2) a meaningful role for risk bearers in risk assessment, risk management and decisions about risk offers the best hope of ameliorating the problems of perceived risk as a cause of social and economic impacts.

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1.0 INTRODUCTION

On August 6, 1987, the U.S. Department of Energy (DOE) sponsored a one-day workshop at the Battelle Seattle Research Center, assembling a panel of experts from a variety of disciplines to discuss the complex dimensions of risk judgment formation and the assessment of social and economic effects of repository-related risk perceptions.[1] The task of evaluating the social and economic effects of repository-related risks was derived from the Nuclear Waste Policy Act of 1982, which established a schedule for siting, building, and operating a repository for high-level nuclear waste from commercial reactors. As authorized by this Act, the Hanford site in eastern Washington was designated by the President in May, 1986, as one of three sites at which a detailed testing program, known as site characterization, would be undertaken to determine the suitability of locating a repository there.[2] The U.S. Department of Energy is monitoring the social and economic effects of site characterization activities, and developing a program to assess the proposed repository's social and economic impacts. Representatives of state and tribal governments, officially designated as parties to the site selection proceedings, have expressed concerns about the potentially significant economic and social effects resulting from a general perception that the repository could pose health and environmental risks.

1.1 Workshop Background

In an effort to gain a better understanding of the impact assessment issues raised by these expressions of concern, the DOE has undertaken a variety of activities leading up to the August workshop documented in this volume. A selective review of relevant literature in psychology, decision analysis, economics, sociology, and anthropology was completed, along with an

[1] The workshop panel was moderated by Dr. Lee Roy Beach (University of Washington). Presentations were offered by:

Dr. Eugene Rosa (Washington State University)
Dr. Ronald Faas (Washington State University)
Dr. Elizabeth Peelle (Oak Ridge National Laboratory)
Dr. Ruth Love (Bonneville Power Administration)
Dr. Chris Whipple (Electric Power Research Institute)
Dr. Steve Rayner (Oak Ridge National Laboratory)
Dr. India Fleming (Battelle-HARC)
Dr. Kristin Shrader-Frechette (University of S. Florida)
Dr. Timothy Earle (Battelle-HARC)

Mr. John Fawcett-Long and Ms. Elizabeth Terrill of Battelle deserve major credit for workshop implementation. Mr. Daniel I. Harbom of the Westinghouse Hanford Company played an important role in the initial discussions concerning approaches to better understanding risk judgment issues in the context of the repository program.

[2] The other two aites so designated are the Deaf Smith site in the panhandle region of Texas, and the Yucca Mountain site in southwestern Nevada. In December 1987, the Nuclear Waste Policy Amendments Act of 1987 authorized site characterization activities to continue at the Yucca Mountain site only. Authorization for site characterization at the other two sites was removed, and all activities at Hanford not related to reclaiming the site were stopped within 90 days of the legislation's enactment.

examination of decision analysis techniques that might assist in developing suitable responses to public risk-related concerns.[3] The workshop, "Assessing Social and Economic Effects of Perceived Risk," was organized as a forum in which a set of distinguished experts could exchange ideas and observations on characterizing the effects of public perceptions that a repository at Hanford would pose environmental and public health risks.

From the outset, the enterprise was fraught with definitional problems. Examining the impacts of *perceived* risk (distinguished from a risk calculated in probabilistic terms) marks a departure from customary impact assessment practice and is therefore controversial. Facility siting and construction have long been recognized to have a wide array of social and economic impacts; the environmental impact statement has become a common document used in federal facility siting decisions. Assessing the effects of major federal actions on the *human environment* (i.e., socioeconomic assessment) is mandated by law and a routine feature of the impact statement. Socioeconomic impacts described in such documents are projected to result from physical environmental changes that would accompany the facility's development. If the proposed facility poses a potential risk to the health and safety to people in the area, special consideration is given to this potential risk in the impact statement. Special precautions may be incorporated into design and construction practice to minimize potential risks, and provisions may be made for emergency response in the event of an accident.

Customarily, the potential risk is calculated by applying one or more of a number of risk assessment procedures (e.g., fault tree analysis, accident scenario construction, and mathematical modelling). Central to most of these procedures is a definition of risk expressed in probabilistic terms; the risk is calculated as the product of the probability of an event's occurrence and the magnitude of the event's consequences over time. The technical specialists who have developed and applied these procedures, have, over time, come to accept these probabilistic expressions as measuring the "real" risk associated with the project. If the general public's expressed concerns over a project's riskiness appear inconsistent with the probabilistic calculation of risk, technical specialists tend to discount the public perceptions of risk as unfounded, ill-informed, or politically motivated. This divergence between technical calculations and non-specialists' judgments of risk is often at the heart of conflict over the merits and disadvantages of undertaking major developments.

[3] For a more detailed discussion concerning the relevant professional literature, the reader is referred to a BWIP technical document entitled "Understanding Socioeconomic Aspects of Risk Perception, Progress Report FY-1987," by E.B. Liebow, J.A. Fawcett-Long, and E.S. Terrill. PNL-6382, BHARC-800/87/023, UC-20e, December, 1987.

We know that significant social and economic impacts may result from a generally-held *perception* that a facility is hazardous. Yet decision-makers must balance the interest in avoiding or reducing such impacts with the need and expense of precautions taken as a result of risk judgments made by non-specialists. Our perceptions are influenced by our knowledge base (i.e., specialist vs. non-specialist), and also by our social values and emotional state. Those who oppose a facility siting for reasons that have little to do with its riskiness could use the perception of risk as a means of legitimizing opposition.

Yet, if we step back from these considerations, it is plainly evident that people act on what they *judge* to be real. Being held up at gun-point with a realistic-looking toy gun is still a frightening experience, and the robber still may get away with the money, even if the toy's *calculable* threat is nil. It is also plausible to imagine limits to economic development in the vicinity of large industrial facilities and reduced marketability of produce from the area if there is the perception that it might be contaminated.

It is because these questions are both important and troubling that it seemed useful to hold a workshop attended by an array of interested parties who could listen to and discuss the views of scientific experts. Given the newness of the notion of impacts of perceived risk, and given its challenge to the traditional practice of defining risk by technical measurements, the workshop was structured as an open forum where ideas could be exchanged and discussed.

1.2 Workshop Synopsis

An unstructured content analysis was used to characterize the presentations by the nine speakers. This procedure simply involves organizing similar ideas and concepts together so they can be conceptualized as a body.

The presentations touched on eight major issues or themes. These issues will be briefly discussed using illustrations from the speakers' presentations. They have been ordered below, not by priority of importance, but to follow a logical sequence that moves from alternative formulations of the problem statement through discussions of the problem to suggestions for bringing improvement. Given the diversity of disciplinary backgrounds and institutional settings from which the speakers have formed their viewpoints, there was a remarkable convergence among the suggestions for improving our understanding of the social and economic consequences of repository-related risk perceptions.

1.2.1 Problems with Risk Assessment

This issue is key to understanding a major difficulty in agreeing on the impacts of estimated risk, i.e., *there is disagreement about how to estimate risk.* As a result, the estimates of risk that are generated by experts applying traditional methods are often rejected by risk-bearers. When risk arises from the development of a facility, risk-bearers usually perceive these to be somewhat greater than those calculated by the experts. The opposite may be true with risks from personal activities such as cigarette smoking and overeating.

Several points were made:

- There are never enough empirical data to be definitive.
- The models used by the risk analyst can bias the results.
- Estimates are averages and thus don't necessarily apply to the case at hand.
- There are large uncertainties in the estimates.
- When new technologies are involved, there is not a body of experience to go on. The idea that the risk assessment made by the "experts" is definitive and that the perceptions of risk bearers are without standing ought to be rejected.

There was general enough agreement on these points among workshop participants that most simply used the terms "calculated risk" or "risk based on probability estimates" in place of the term "real" risk.

In other words, assessment of the "real" risk is beyond definitive capability. The thrust of this theme is to lend greater legitimacy to a range of approaches to risk assessment, and to a range of perceptions of how serious risk is in a given case.

1.2.2 Differences in the Way Experts and Laypersons View Risk, and How This Leads to Higher Levels of Public Concern Than Experts Feel Are Justified

Nearly all of the speakers touched on this issue. Among the points made were the following:

- Experts define risk as the product of the probability times the magnitude of the consequences of an event, while lay persons have a broader, more holistic sense of risk.

- Viewing risk perception--as the psychometric paradigm does--as an individual judging the relative risks of various activities, is too narrow and excludes important social influences on risk perception--social influences to which the expert may also be susceptible.

- Adaptation to hazards and the ability of a person to manage a hazard have important influences on perception of risk.

That risk bearers often perceive risks to be greater than those estimated by the professional risk assessor is obvious. This theme has major bearing on the question of impacts from perceived risks. If all risk bearers agreed that the risks of a proposed activity were minor, then indeed there might not be any substantial social and economic impacts attributable to the activity. However, since risks may be perceived as large, despite the expert estimates, they could have substantial social and economic impact.

1.2.3 Experts, Risk Managers, and Decision-Makers Sometimes Err In Assessing Risk and In Dealing with the Public

Again, many speakers touched this theme. Among the points made were these:

- experts focus on the small probabilities of negative events and appear to take the position that "it can't happen," while laypersons focus on the consequences because "it *could* happen," thus both experts and lay people violate the principles of decision-making.

- Experts are seen to be insulated from consequences and thus their estimates are suspect.

- Experts view the public as needing "education"--this arrogant approach leads to conflict and hampers public understanding and acceptance of risk assessments.

- Instead of trying to change public perceptions of risk, risk managers should encourage stakeholder involvement in decisions--this improved sense of control may improve the credibility of the risk assessment.

- Risk managers should not cut corners by eliminating low-probability risk scenarios, and should be ready to cope with anything that can be foreseen.

In other words, risk managers should pay more attention to reducing risks and less to convincing people that the risks are too small to be concerned about.

These points help explain how experts and lay people sometimes disagree and how lay people can view risks as serious enough to cause social and economic impacts, even if experts don't.

1.2.4 Credibility and Trust

Several speakers commented on how important it is that the agency developing a facility maintain credibility and trust. Judgments about risk among members of the general public are often based as much on the managing agency's credibility as on the reliability of the engineered system. Among the points made:

- The federal government has poor credibility.

- The credibility of and trust in those managing risks is key to acceptance of risk.

- Public involvement can improve credibility.

- Efforts to manage risks will improve credibility.

- People trust people, not technologies *per se*..

Again, it the risk assessments of experts were accepted by all, questions of the impacts of perceived risk would be somewhat less troublesome. The thrust of the speakers' comments on trust remind us that *risk assessment and risk management are done by people. If those people are not judged to be trustworthy and credible, neither will be the assessment.*

1.2.5 Consequences of Perceived Risk

The workshop participants spent relatively little time discussing the social and economic impacts that might result from perception of risk. This may well reflect the relative novelty of considering this category of effects in the practice of impact assessment. However, several points were made:

- Stress is a consequence of perceived risk--an existing danger or threat is likely to have little effect unless people are aware of the risk.

- Uncertainty and not having control of events that may cause harm produce stress.

- People react to stress by trying to solve the problem that is the source of risk, or by emotional coping.

- Public reaction to perceived risk should be considered in economic, political, and social spheres of activity.

- There are several approaches to measuring the link between perception and behavior, including interviews with people who move from an area, to determine if siting a facility is a causal factor.

Workshop participants were nearly unanimous in agreeing that, yes, perceived risk can indeed cause impacts, even in situations where calculated risks are trivial.

These views remind us of the diverse nature of possible impacts of perceived risk and point us toward the need to better understand the linkage between perception and behavior involved in reacting to risk. Simply because one sees an effect does not necessarily mean that environmental risk judgments are the cause. On the other hand, people may form strongly-held beliefs that something is risky, yet not act because they do not feel they have sufficient influence to reduce the risks they judge to be present.

1.2.6 Informing the Public About Risk

This topic was infrequently touched on. The main points included:

- Problems with informing the public stemmed partly from an assumption that the experts are right and the public is ignorant.

- Providing information is a difficult challenge because there is wide diversity in what people consider to be information that is relevant to them.

- Experts can't readily predict what information people want.

There was general agreement that *the question of social and economic impacts of perceived risk will not go away as a result of even the most strenuous public information efforts.* Public information must be combined with other remedies.

1.2.7 The Role of the Public in Risk Assessment, Risk Management and Decisions About Risk

Most speakers commented on this topic. To the extent that the workshop produced suggestions for ameliorating the problems discussed above, most fell in this topic area.

Among the points made:

- Informed consent and involvement of risk bearers in decisions affecting them is necessary but not sufficient to bring about conflict resolution.

- Fairness is an elusive quality and hard to achieve--it involves issues of consent, liability, and trust.

- Ours is a diverse society, with multiple viewpoints concerning the appropriate way of gaining consent to being placed at risk.

There were several suggestions by the speakers about how to bring about public involvement. Besides the usual hearings, these included citizens advisory groups, surveys of public concerns and priorities, stakeholders' participation in the ongoing decision process, and stakeholders involvement in monitoring activities--perhaps even monitoring the consequences of perceived risk.

Key to these recommendations regarding public involvement are: (a) there must be a genuine and authoritative role for stakeholders in decision-making, the so-called "DAD" approach (Decide, Announce, and Defend) was decried; and (b) close attention must be given to the public's concerns, even if these don't seem of much concern to the experts.

1.2.8 Mitigation and Compensation

Few comments were made on these topics, except to point out that they were necessary, but no substitute for public involvement in the decision-making or for making the best effort possible to reduce and manage risk.

1.3 Conclusions and Report Organization

As noted above, it was not expected that the workshop would come up with definitive results. However, it seems fair to conclude that these speakers generally agreed that perception of risk could cause social and economic impacts and that this topic ought to receive continuing attention as a means of reducing the social and political conflict that marks nuclear waste siting actions.

The nine speakers at the workshop followed an informal format in making their presentations. The summaries that follow in Sections 2 through 10 were developed by the workshop organizers and edited, or rewritten in some cases, by the authors. They are intended to convey the main points the speakers made, but are by no means a complete record of the workshop's content.

2.0 THE SOCIAL CONTEXT IN THE FORMATION OF PERCEPTION AND ATTITUDE TOWARDS RISKS

Dr. Eugene A. Rosa
Washington State University

Perception and response to the risks associated with a high-level waste repository are of central concern in any form of socioeconomic impact analysis. Research on risk perception is dominated by a psychometric paradigm that emphasizes the use of cognitive "rules-of-thumb," or heuristics and other mental strategies to process risk information. Occasionally these strategies produce valid perceptions of risk, but more often than not, the perceptions are systematically biased. The psychometric paradigm, flawed both theoretically and practically, requires modification if it is to be fruitful in assessing perceived risk and in devising policy options for addressing concerns about risks.

Key theoretical shortcomings of the psychometric approach are, first, its assumption that perceptions are the result of a singular temporal process, second, its virtual neglect to link perceptions to risk responsive behavior, and third, its total neglect of the social context in which perceptions are formed, a context well known in the social science literature to influence perceptions. The singular process assumption is contradicted by numerous examples where an individual adopts an attitude or behavior and then, after the fact, forms a perception consistent with the attitude or behavior. The adopted attitude or behavior in such circumstances serves as an anchor to filter risk information in a way that maintains consistency between the former and latter. Furthermore, while the psychometric approach assumes a causal link between perceptions and behavior this link is virtually untested empirically. Finally, the entire field of social psychology is built, and well supported empirically, on the foundation that social actors do not see the world with pristine eyes, but with eyes filtered via the influences of family, friends, co-workers, and trusted public officials.

Suggested here is a modified, social psychological approach that specifies dual temporal processes to the formation of risk perceptions, that incorporates the importance of social influences on perceptions, and that strengthens the link between perceptions and behavior.

The psychometric paradigm is similarly flawed in its approach to incorporating public concerns about risk in policy decisions. It typically follows a "top down" approach where a pre-selected taxonomy of risks is presented to the public. Invariably, the results show a discrepancy between their estimates and the actual risks of the taxonomy's items. There are a number of disturbing

difficulties with this approach, not the least of which is that predetermined lists of risks typically include some of little concern to the public while excluding important concerns. Omitted concerns are particularly troubling because of their inevitable biasing of general risk assessments.

The social psychological model accommodates a "bottom-up" approach to risk assessment that involves the public in all stages of the process: in defining and comprehending important risks, in forecasting impacts, in defining remediation or mitigation strategies, and in developing equitable compensation programs for un-remediable and unmitigable impacts. This approach seems far more likely to reach siting decisions that are acceptable and equitable.

3.0 RISK OF ECONOMIC LOSS TO FAILURE OR PERCEIVED FAILURE OF A REPOSITORY

Dr. Ronald Faas
Washington State University

Experts and lay people differ in their assessment of risk. Experts often emphasize probability (i.e., annual fatalities) to form risk estimates, whereas lay people focus on consequences (i.e., future implications). Both the expert and lay person violate the principles of decision-making. The differences between estimates made by experts and lay people are illustrated in low-probability/high-consequence events. The lay person tends to emphasize the high-consequence component of risk if the probability is even slightly over zero, a "Type 1" error. The expert in a similar situation will focus on the low-probability component of risk and ignore the consequence, a "Type 2" error. These decision errors have significantly different ramifications (Table 1). The Type 1 error, falsely predicting catastrophic outcome from a relatively safe situation, is more conservative and may result in the person rejecting any progress in a technology that may involve some degree of risk. In contrast, the Type 2 error, falsely predicting safe outcome from a catastrophic situation, may result in a potentially dangerous situation being overlooked.

The cranberry scare some years ago is a practical illustration that given some probability of failure, people who perceive high consequences behave in a manner that affects economic value. Although the ban was removed from cranberries earlier thought to be contaminated, people chose not to purchase or consume cranberries that year, causing an economic impact sufficiently severe that Ocean Spray initiated an intensive diversification program in response. Thus, economic loss depends not only on expert judgment of actual physical effect, but on how people react to what they think the consequences to be and the probability of them occurring.

Given that there is no risk-free environment, national policy must allocate exposure to risk. Two basic choices and risk impacts follow: 1) accept for society the Type 1 error and reject siting everywhere, or 2) proceed with siting somewhere and impose exposure to the Type 2 error upon the impacted region. The Type 2 decision raises the following two mitigation issues: 1) under what conditions should an area accept exposure to a potential failure to predict a catastrophic outcome, and 2) Could alternative institutional designs more effectively tie exposure to consequences with reduced probability? If those who make decisions affecting probability were to be exposed to the consequences, would they have more incentive to drive the probability affecting exposure to risks closer to zero?

Table 1. Comparisons of Alternative Risk Choices and Alternative Failure Outcomes

Choice of Risk	Outcomes of Failure	
	Low Consequences	High Consequences
Accept risk of HLNW repository failure:	No catastrophic consequences will occur	Type II error - fail to predict catastrophic consequence by presuming safe situation
Avoid risk of HLNW repository failure:	Type I error - falsely predict catastrophic consequence when situation is safe	Catastrophic consequence if repository fails (but avoided by avoiding risk of failure, not siting repository in area).

In contrast, current mitigation policies appear to insulate consequences from those who could affect probability. For example, during the 1987 Congressional debate on raising the Price-Anderson Act limits, industry and financial experts argued that the risk as perceived by informed financial markets was too high for the industry to bear without increased protection. Yet, pleas by community officials for measures to limit community exposure to those same risks are often labelled as uninformed, emotional, or in worse terms. Similarly, while the cost of an effective performance bond or comparable assurance is considered unrealistically expensive for the USDOE or the generators of nuclear waste to absorb, current public policy effectively shifts that exposure to an impacted public unable to bear the high transactions cost of obtaining relief from catastrophic consequences, should such occur.

This framework provides insight as to why "scientific" claims of low probability by those insulated from catastrophic impacts may be perceived as lacking credibility by others most likely to be exposed to high consequences of repository failure.

4.0 RISK-BENEFIT PERCEPTION: THE RESEARCH CHALLENGE

Dr. Elizabeth Peelle
Oak Ridge National Laboratory

Factors predisposing the general public to regard repositories as risky include the nuclear track record of secrecy and ineptitude, the overconfidence of some pro-nukes, and the premature commercialization of an immature technology. Then, in parallel, we have the AEC-DOE track record including a bureaucratic approach involving premature policy decisions and continual changes in nuclear waste policy as demanded by Congress. Confounding nuclear power with nuclear weapons is encouraged by those whose goal is to eliminate nuclear power. Media coverage feeds on controversy and crisis -- a major factor in the general public perception that nuclear power and repositories are risky.

Beyond their actual physical effects, there is the "signal value" of accidents such as Browns Ferry, Chernobyl, the Hanford tank leaks, the Challenger disaster, and Three Mile Island. These accidents, as Paul Slovic might say, have signaled that either the managers and operators don't understand the technology well enough to manage it, or worse yet, that the technology itself may not be manageable. With woefully inadequate science and technology education, U.S. citizens are unprepared to make decisions about management and uses of technology or to conduct their own risk evaluations. All of the above is occurring against the backdrop of the widespread and pervasive decline of trust in government and institutions in the past 25 years. And, finally, there is Murphy's Law--everyone has some personal knowledge that whatever can go wrong will go wrong some day. In this social context, the tilt is toward perception of repositories as risky.

As Roger Kasperson and his colleagues at Clark University might point out, among social amplifiers of risk lack of trust is primary. Discussions cannot begin without some minimum level of trust. There is great skepticism about the information offered by developers or the government. Risk can be further amplified by lack of involvement in decision making, the stigma of the proposed activity and low agency or manager credibility. Despite the possibilities for structuring the siting process offered in the Nuclear Waste Policy Act, the unstructured siting process with limited public input, otherwise known as the "DAD strategy" (decide, announce and defend) was still used in 1985 with the Monitored Retrievable Storage facility siting in Tennessee. Major uncertainties in the factual base, future outcomes and impacts all contribute to social amplification of risk. Therefore the current volatile, fearful public attitudes toward nuclear waste will likely continue.

The research challenge is to define the linkage between judgments and behavior, the perennial unsolved problem. What are the bridging assumptions that enable us to cross this gap? How and under what circumstances do those judgments get translated into action?

The proposed research in the BWIP program deals with only half of the spectrum of risky/non-risky perceptions, ignoring perceptions of safety or non-risk. In fact, we don't even know if attitudes are arrayed in a continuum or if they are stochastic or lumpy. What are the boundaries between perceptions of safety and risk? How do people make decisions that something is safe or that it's not? We know a lot more about the psychological components of decisions on risk, thanks to Paul Slovic and his colleagues than we do about the social conditions and components. How do people move from one category to the other? Is it a one-way street as some have claimed in stating that "it's a lot easier to scare people than it is to un-scare them?"

If the latter is true, how do we avoid the self-fulfilling prophecy? We already know that the more information presented about safety and risk, and the more debates between experts about safety, the greater is the public's concern and reluctance. Are we enhancing perceptions of risk by the way the research problem is formulated and setting up a self-fulfilling prophecy in the process? Interactions between experts and the public did not appear in the proposed research agenda.

More specific problems with the proposed research agenda included not specifying which risk framework was chosen and assuming that the distribution of risk is stable. Perception of risk is more important in your research agenda than perception of safety (or non-risk). The two are certainly related, perhaps inversely and it's that relationship and the boundary between the two that needs clarification.

The proposed research could be strengthened by refocusing upon a major role you've articulated: enabling credible risk management. Focused research leading to risk management action ought to be the criterion. A guiding principle might be the analogue of one discovered repeatedly by social impact analysts: it is probably easier to manage risk perceptions than it is to either define or quantify them. Among the empirical findings and direction guides available are Stan Nealey and Linda Radford's work on excessive fear of nuclear power and the Oak Ridge National Laboratory work on incentives, compensation and benefits.

The components of the risk-management challenge include at least the following: First, there is the challenge of affecting judgments on repository risks by involving the risk-bearers in decision making, providing for local oversight, and reducing the social amplification of risk. The prospect of local control as proposed by the MRS citizen task force in Oak Ridge was among several factors that led to a decision

that the facility could be safely managed. Second, there is the challenge to DOE to improve its track record during the repository siting and construction process.

We need measures to increase interaction between the risk bearers and project promoters and managers. Trust can be **created** by involving people in the process, letting them see DOE's trustworthy people and their serious efforts to do right by the risk bearers. Trust can be created by DOE as it makes a new reputation through its actions and becomes known as a reliable, trustworthy entity. Thus DOE is taking risks, too, by letting risk bearers into the decision process and becoming part of it. Yes, there is danger of the process being used in a manipulative manner, especially if DOE is not serious about trying to implement the spirit of consultation and cooperation in the NWPA. But I believe that such a process, entered into seriously on both sides, will significantly alter the perception of risk on the part of the risk bearers.

Finally, for practical and ethical reasons, we need to increase the benefits to risk bearers. Benefits are not the whole story. They cannot be used to "buy off" people who see risks to their health or safety. **After** the safety questions have been answered to peoples' satisfaction, then they are willing to consider benefits. But assuming that this precondition is met, then we need to develop arrangements for compensating and rewarding risks bearers for inequitable distribution of risk. The risk management challenge is a big order, including not only these difficult tasks but also the need to reduce fear, while avoiding a solely manipulative approach. But we know how to begin addressing most of these problems and that enables us to move ahead.

5.0 WHAT COUNTS: PERCEPTIONS OR ACTIONS?

Dr. Ruth L. Love
Bonneville Power Administration

I chose this title because we have a tendency to assume that we act consistently with our perceptions of risk. That is by no means always the case and subject to empirical verification.

While I was preparing for this conference I came across a news article about a Chrysler plant in Delaware where work exposure to lead, arsenic and other dangerous chemicals is very high. According to the Occupational Safety and Health Administration (OSHA) the situation in the plant is unacceptable. The unionized workers worry that if they press for plant improvements Chrysler might close the 30-year old plant. Thus jobs might be lost. Here the workers are balancing the risk of job loss against the risk of ill-health in a situation that is not clear cut because Chrysler claims it has and will continue to improve conditions. The point of this news article is to illustrate that people may be willing to accept some risks to avoid other risks.

Another general point I'd like to make is that people act in many spheres or arenas of action--the political arena, the economic arena, the religious and familial arenas, and so forth. To the observer, an individual's actions may not appear consistent from one arena to the next. Thus a resident of Portland, Oregon might be politically active in the nuclear repository siting controversy while living only 30 miles away from Portland General Electric Company's Trojan Nuclear Plant.

Finally, to finish these background remarks, it is not at all clear to what extent people take the presence of nuclear facilities into account when choosing to start a business or take up residence in an area. Thus Washington and Oregon experienced major population growth during the 1970s, at the same time that construction began on the now ill-fated Washington Public Power Supply System (WPPSS) nuclear plants.

5.1 Linkage of Risk Perception to Economic, Social and Political Action

I think we should treat these linkages as potential linkages until we have data to support them.

From past studies we already know that there is some linkage between perceiving a nuclear repository as risky and taking political action. Although certainly only a small percentage of persons who perceive

repositories as risky do take political action. We also know that the nuclear power industry has fallen on hard times, partly because of concerns about safety and environmental impact.

But I think we know much less about the linkage between risk perception and economic action. There is a legitimate concern among public officials in Washington State that merely naming an area as a candidate repository site could have adverse effects on economic growth and development prospects. That is a reasonable hypothesis.

Suggestions for examining the hypothesis:

1. Go back to the Harrisburg area now that about eight years have passed since the TMI incident. Have the secular economic and demographic trends been affected by TMI? Are people moving in and out of the area as they ordinarily do? Are businesses moving in and out of the area as they ordinarily do?

2. Focus in on persons and businesses moving recently into localities adjacent to nuclear facilities. Have a nationally respected pollster such as Lou Harris design a study to ascertain what factors influenced people's moving decisions. Here our interest would be on whether people were aware of the nuclear facility in the vicinity and whether it played a role at all in their decision to move into the area. And of course we would also be interested in their perceptions of nuclear facilities.

3. Likewise, focus on persons and businesses who have recently left a locality near a nuclear facility and find out to what extent fear of the facility contributed to the decision to move.

4. Start socio-economic monitoring of the Tri-Cities, Washington area immediately and try to reconstruct past demographic and economic trends in the area. The same should be done for the other candidate sites to test the hypothesis of possible links between perceptions of dread, risk, and social and economic processes.

The findings from such studies should help in planning for managing the long term social and economic effects associated with the presence of a nuclear repository.

5.2 The Problem of Nuclear Repository Management Credibility and Competency

There is also need for responding to risk perception per se as well as the possible social and economic fallout from such risk perception. Let us assume for the moment that we learn from such studies as outlined above that there is no or little linkage between perceptions that nuclear repositories are risky and social and economic actions that can affect the future well-being of the repository area. This does not mean we should ignore the risk perceptions. What it does mean is that risk perceptions can lead to actions mainly in the political arena. So that is an arena that will require some impact management in any case.

Again, in preparing for this meeting I came across the results of a Lou Harris poll commissioned by the U.S. Office of Technology Assessment, which is an office that serves Congress. A sample of 1,200 adults was asked how likely they would be to believe statements about the risks from biotechnology if the statements were made by different types of people such as university scientists, public health officials, Federal agencies and so forth. Since biotechnology includes genetic engineering of organisms such as bacteria, some of the same fears associated with nuclear power could be attributable to biotechnology. So the poll results have some bearing on the subject matter today.

It turns out that we are quite willing to believe university scientists when they make risk statements about genetic engineering. And we are almost as likely to believe public health officials. And we tend to believe environmental groups. But we are somewhat less likely to believe Federal agencies, especially if, say, the environmental groups and Federal agencies disagree about a potential risk. But we are much more likely to believe Federal agencies than we are local officials, companies making the product in question and the mass media.

In regard to biotechnology, at least, the Feds have a bit of a credibility problem. I would expect that if a similar poll were taken in regard to risk statements about nuclear repositories the results would be similar.

The credibility problem is probably a contributor to the perception that nuclear repositories are risky. One way to manage this and to try to reduce adverse political grass roots activities in the future would be to form citizen advisory groups that can do these things:

1. They can represent the concerns of the community to the repository managers.

2. They can be permitted, at a very early stage, to review plans, for operating the repository, safety features, training, staffing levels, management of repository workers, emergency provisions,

etc. and to raise critical questions concerning the adequacy of these plans--in effect, a citizen quality control board on all aspects of long-term operation and maintenance of the repository.

3. A similar board would review the transportation of nuclear wastes to the repository.

Service on such boards should follow accepted democratic procedures such as those used for elected school boards. Such citizen boards provide a legitimate and potentially meaningful and important outlet for political action.

If the citizen boards can avoid cooptation by repository managers, the boards can help insure that people are properly trained in safety procedures, that staff is not overworked, that schedules are properly covered, that safety equipment is being properly maintained and so forth--all factors which have apparently contributed to some near-miss incidents in nuclear power plants as well as contributing to the Chernobyl disaster.

Also much can be learned from how the natural resource agencies handle public involvement and citizen input for managing their programs.

5.3. Summary

1. Don't assume automatic linkage between risk perception and economic action. Instead, look at past behavior in appropriate settings.

2. Manage effects from a political standpoint as well as economic and social standpoints (citizen boards).

3. Equity: We have chosen to use nuclear power so we should pay the price of disposing of it--offer a carrot to the locality housing the nuclear repository. The definition of the carrot needs to be worked out through a grass roots partnership with Congress and DOE. The carrot might be in the form of grant money to build social and cultural facilities that are needed but could otherwise not be afforded and which would enhance economic development in the area.

This type of planning for equity can compensate for the uncertainties associated with trying to manage social, political and economic effects that can result from a large, dreaded undertaking.

6.0 JUDGMENT AND ACTION IN HAZARD ADAPTATION: APPLICATIONS OF NUCLEAR WASTE MANAGEMENT

Dr. Timothy Earle

Battelle Human Affairs Research Centers

One may not assess the impacts of judged riskiness until one understands how riskiness is judged. Experts and technical engineers tend to define risk in terms of a small number of specific measures, such as mortality and morbidity. Conversely, lay persons may use a wide variety of approaches. As a result, it becomes difficult to communicate information about a particular hazard, as some information may be considered pertinent by some and less relevant by others. By and large, the technical engineer is interested in what is known about a given risk. Conversely, psychologists are more interested in how one knows about the risk and forms judgments about these risks. The Lens Model, developed by Hammond, offers some insight into the judgment process by assessing what aspects of a hazard people believe are important. In addition, the model generates descriptions of how people assess risks through process tracing (i.e., people "think out loud" as they process information about the hazard.) Nuclear waste activities are intrinsically complex and controversial. A better understanding of how judgments are formed may possibly allow nuclear waste management to be improved and, through effective communication, become acceptable to a wider range of people.

Hammond, a psychologist in the field of judgmental decision making, has introduced the Lens Model which serves to illustrate the interaction between an individual's model of the environment and his implementation of the model to form judgments. This model, not solely based on risk, measures the judgment of a particular hazard and the person's ability to manage or cope with the hazard.

The Lens Model was used in a case study at the Hanford site. Participants included both experts and laypersons. They worked on a task which allowed them to freely acquire information about the management of defense nuclear wastes. Each participant specified the type and source of information he required before choosing between alternative management plans. Results showed that experts and laypersons preferred different types of information from different sources. The two groups also favored different management plans.

This study demonstrates that technical experts within the nuclear waste management field must adjust to the information needs of the public in order to improve communication on this important public issue.

7.0 ISSUES OF TRUST IN FACILITY SITING

Dr. Steve Rayner
Oak Ridge National Laboratory

Public perceptions of threats posed by potentially hazardous technologies frequently differ from the actuarial or probabilistic risk assessments of experts. This is because experts tend to confine themselves to an engineering-type definition of risk, as the product of probability estimates and human-health consequences for a specified time period. Non-experts tend to employ an expanded definition that includes risks to the whole of their lifestyles. Thus, issues of consent to risk, distribution of liabilities and benefits, and trust in risk-management institutions may eclipse the probability of adverse health effects in shaping public responses. Because consent, liability, and trust factors are harder to express quantitatively than probabilities of mortality, probabilistic risk may become the vehicle for the expression of societal risk concerns.

Judgments often are thought of as dictating actions although, in reality, actions may be the drivers of judgments. For example, someone who dislikes the location of a waste repository would have a greater impact on the siting process by showing a health threat, than by more simply stating that they want to preserve their neighborhood just the way it is. However, both health and societal concerns are legitimately intrinsic elements in any complete definition of risk. Risk is polythetic in nature and, therefore, the definition includes seemingly unrelated parts that combine to form a complete definition. A step to improving risk management involves becoming aware of all of the factors that make up a risk.

Expanding the definition of risk to include threats to societal institutions and lifestyles highlights an uncomfortable truth about risk management. It inevitably includes a component of people management. We don't like to think of managing or manipulating the public in a democracy. But that is exactly what we do when we try to convince the public to conceptualize risk the experts' way; the process we call risk communication.

Unfortunately for the risk manager, the people with whom he deals not only differ from experts in their definition of risk, they differ from each other in the ways they prefer to resolve the issues of trust, liability, and consent. The emergent problem for risk managers, therefore, becomes one of social conflict resolution rather than one of engineering public perceptions.

Several studies have described consistent differences in risk behavior between four types of stakeholder: 1) entrepreneurs, consisting of people whose social interactions are characterized by competitive market behavior; 2) bureaucrats, who operate in a variety of hierarchical groups; 3)

egalitarians, who are members of small voluntary groups; and 4) atomized individuals, who are usually subject to social stratification but are not members of distinctive groups.

The findings of these studies suggest that the entrepreneur determines people's preferences by observing market behavior. This approach also is referred to as the revealed preference approach. Entrepreneurs also favor market solutions, like insurance, to distribute liability. Bureaucrats, on the other hand, tend to rely on hypothetical consent; the principle that if we accept the legitimacy of social institutions, we consent to their decisions. They also favor redistributive taxation for spreading losses. The egalitarians look for explicit consent expressed in public forums. Egalitarians also favor strict liability for losses so that those held responsible for an accident have to bear the cost. The atomized individual finds it difficult to be heard and prefers to avoid unfamiliar risks altogether.

Each type of stakeholder has a characteristic conceptualization of the future that is relevant to high-leve waste storage. Oversimplifying, it appears that egalitarians and atomized individuals have less confidence in present actions to mitigate impacts on future generations than the entrepreneurs and bureaucrats. This variation among organizational cultures leads to social conflict. Consensus among stakeholders is necessary to form acceptable policy and should be started early in the planning process. In the effort to create policies that will be acceptable to a wide range of people, risk managers need to accept the legitimacy of stakeholder viewpoints in the decision-making process and to place more weight on issues of fairness and trust in establishing risk-management processes and institutions.

8.0 STRESS AND THE PERCEIVED RISKS ASSOCIATED WITH NUCLEAR WASTE

Dr. India Fleming
Battelle Human Affairs Research Centers

This presentation focuses on the individual-level consequences of the perception of risk, particularly on stress. The stress process, stress response, and consequences of stress are discussed within the context of the types of risks most likely to be perceived during the construction and operation of a nuclear waste repository. The content of these comments is based on research involving people residing near the Three Mile Island (TMI) nuclear power plant and people residing near hazardous waste dumps. An understanding of these psychological processes may be useful in mitigating public concern about radiation-based technologies and stress resulting from activities involving nuclear waste.

The psychological response to risk depends upon the perception of risk rather than on the actual risk inherent in a situation. Thus, from a psychological perspective, an existing danger or threat will have no effect unless people are aware of the risk; similarly, the perception of a risk can have a significant psychological effect even if there is no objective danger.

Stress is a psychological and physiological response to the perception of a threat. The stress response is characterized by emotional distress, deficits in cognitive functioning, and physiological arousal. If stress persists, serious psychological and physiological problems may develop. The most widely accepted model of the stress and coping process was proposed by University of California psychologist Richard Lazarus. He described a two-step process involving appraisal of the threat and appraisal of one's resources to cope with or minimize the danger. If a situation is appraised as dangerous then an individual will examine options for coping. There are two general categories that describe coping behaviors, these are: problem-focused coping and emotion-focused coping. Problem-focused coping involves changing the risks inherent in the situation or removing oneself from danger. Emotion-focused coping involves modifying one's emotional response to a threat.

Exposure--or perceived exposure--to hazardous substances such as radiation and toxic chemicals may be significant sources of stress. The perception of risk may occur even during normal operation of a nuclear waste repository, however, there are few data at this point to indicate how likely it is that this will be a significant source of stress. Data from other situations, including TMI, clearly indicate that perceived risk will almost certainly cause stress in the event of an accident causing even minor environmental contamination. Exposure to radiation will be appraised by most people as posing a real threat. Further, once a person believes, whether correctly or not, that he or she has been exposed to radiation there is little that an individual can do to minimize the danger. Two characteristics of situations involving the

perceived exposure to hazardous substances may be potent sources of stress. First, these situations may threaten people's sense of control, and perceived control is a critical mediator of the stress response and of one's ability to cope with a threat. Second, the perception that one has been, or even may have been, exposed to a hazardous substance such as radiation may lead to feelings of uncertainty. Feelings of uncertainty about the risk or its consequences (e.g. increased worry about cancer and birth defects) are potent sources of stress.

Research at TMI and other hazardous waste sites suggests that the perception that one has been exposed to radiation or a toxic chemical is a significant source of stress. It is important to keep in mind that people respond differently to threats involving radiation; not everyone living near TMI showed elevated levels of stress. In that situation, elevated levels of stress were associated with perceived lack of control, concerns about future health and well-being (uncertainty), and problem-focused coping. The impact of coping style is probably due to the fact that, in that situation, people utilizing problem-focused strategies, such as participating in legal battles to shut down the other reactor, largely failed to accomplish their goals.

This analysis suggests that mitigation strategies that enhance people's sense of control regarding the risks they face and that reduce their uncertainty about the risks may minimize perceived risk and increase effective coping. For example, involvement of the affected communities in planning and overseeing a repository may enhance perceived control. As noted, an important part of the appraisal process involved assessing what can be done to minimize the risk. There is little that individuals can do to minimize the risks associated with a nuclear waste repository, however, feelings of control may be influenced by whether they trust the people responsible for managing the risk.

9.0 ETHICAL RESOLUTION OF RISK CONFLICTS

Dr. Kristin Shrader-Frechette
University of South Florida

Many risk assessors allege that, whereas the expert provides information about "real" risk, the lay person merely subscribes to ideas about "perceived" risk. In reality, however, there is no legitimate difference between real and perceived risk. All risk is perceived, but to a greater and lesser degree. The assessment of real risk requires a state of certainty that is not possible, especially when dealing with new technologies whose accident frequencies are unknown. In addition, knowledge of real risk cannot be attained because 2) there is a lack of sufficient empirical data; 3) the use of particular risk models creates biases; 4) data on risk are drawn from averages that are generated relative to particular locations and individuals, data that often cannot be applied to different situations; and 5) risk estimates are never precise, but often only specify a range within which a risk is thought to occur.

Given all these difficulties with specifying risk in any objective way, how can conflict between experts and lay people, over defining acceptable risks, be reduced? How can agreement concerning risk decisions be reached? Mitigation of risks and negotiation about risk acceptability and risk distribution are necessary, but not sufficient, to address both these issues. To adequately resolve the conflicts between experts and the public, risk assessors should shift their emphasis away from differences between expert and lay opinions about acceptable risks, and instead concentrate on the resolution of political and ethical differences underlying the two accounts of risks.

As a first step in this direction, government should attempt to insure both that potential victims are able to give free, informed consent to virtually all risks they bear and that they receive compensation for the unavoidable risks and costs to which they are subjected. Medical ethics supports rights to informed consent, and it is reasonable to think that similar rights should be granted to those bearing the technological risks of society. Likewise, the Fifth and Fourteenth Amendments (to the U.S. *Constitution*) support the rights to due process and therefore to compensation for harms. These same rights also should be granted to risk bearers. There are arguable ethical grounds for extending the notions of rights to include them. The purpose of recognizing this extension of Constitutional guarantees, however, is not to "buy" people, by compensating them for the risks and costs they bear, but to distribute risks more equitably and fairly.

Although controversies involving risk distribution may never be solved, it would be beneficial to look at case studies of environmental controversies that have been successfully resolved in order to find a workable solution to conflicts involving acceptable risks. Consideration of a number of such cases

indicates that it would be reasonable to devote less time trying to solve scientific problems associated with acceptable risks and more time attempting to resolve the relevant political and ethical controversies

10.0 CREDIBILITY IN NUCLEAR WASTE MANAGEMENT

Dr. Chris Whipple

Electric Power Research Institute

Public perceptions of the potential risks of high-level radioactive waste (HLW) management alternatives will play an important role in political choices regarding the "how" and "where" of waste disposal. The importance of risk perceptions in setting policy for controversial technologies has long been recognized, and much good research has been done to explore the nature of risk perception in connection with risks of different types. Perception of the risks from nuclear power plants have been the focus of much of this research; studies have linked the perception that nuclear power risks are great to certain qualities of the risk, in particular to perceptions that the risks are catastrophic, new, uncertain, and involuntary or beyond individual control. HLW poses risks with similar characteristics; the risk is uncertain and novel, the time horizon of current decisions is long, and the health concern is cancer.

10.1 The Nature of Risk from a High-Level Waste Repository

There is no actuarial basis from which to assess HLW risk. Some scenarios for risk include low-probability/high-consequence events such as volcanos, others are based on serious, irreversible changes over extremely long times, for example, climatic changes that could increase rainfall at a repository site.

The actual performance of a repository is difficult to assess. Releases are likely to be invisible and diffuse; effects that might occur would be difficult to associate with causes, especially considering the long latency periods associated with cancer. It is clear that the magnitude and nature of HLW risk is not easily analyzed and that quantitative risk estimates will be highly uncertain and subject to challenge.

10.2. Alternate Decision Models

Implicit in the interest in public perception of HLW risk is the idea that people intuitively balance perceived risk and benefit. My purpose in this short paper is to suggest an alternate framework for thinking about public perceptions regarding HLW. My thesis is that most people do not judge HLW risk by considering the technical details of HLW disposal, but rather reach judgments about whether to trust the people and institutions involved in waste management. While most people have little experience or knowledge pertaining to radioactive waste, they have considerable experience in evaluating other people. The issue is perceived risk management, not perceived risk.

If it is true that judgments about HLW disposal proposals will be based in large part on the trustworthiness of the team implementing the program, then there is cause for guarded optimism regarding the prospects for public acceptance of a well-managed waste management program. While there is little that can change the troubling characteristics and uncertainties of HLW risk, the perception of the integrity and competence of the risk managers depends in large part on their performance and in their dealings with the public.

10.3 Factors Influencing Credibility

Many factors influence the credibility of the DOE and its contractors in their efforts to develop the first HLW repository. Given the highly polarized reactions to radioactive waste disposal, it is reasonable to anticipate that criticisms and challenges to the technical competence and integrity of the work will be made. How DOE responds to such criticisms will be one factor affecting its credibility; conversely, DOE's credibility will have a significant influence on its ability to respond effectively when unjustified criticisms are made.

The incentives that DOE and its contractors have, to find a proposed site and technology for waste disposal suitable or unsuitable, will influence DOE credibility. The fact that DOE has the mission of developing a site, and that findings that would disqualify a candidate site would stop work at that site (leading to loss of work for the contractors at that site) contribute to the perception that DOE and its contractors have an inherent incentive to disregard or down-play troubling findings.

A partial remedy to this potential source of bias is through a carefully designed process for evaluation and licensing. The credibility of the site characterization effort will be aided by openness and scrutability, by opportunity for participation by state and local groups and individuals, and by the nature of reviews and oversight established for the process. Specification of a siting process that is structured to reveal errors, optimistic assumptions, or omissions is a central aspect of current HLW policy, as embodied in the Waste Policy Act.

While the elaborate process for state and NRC review of DOE's analysis and the perceived incentives for DOE and its contractors to find a site suitable are important factors in DOE's public credibility, their role should not be overstated in comparison to the working relationships established between the project staff, state and NRC oversight groups, independent review groups, the press, and members of communities near the site under consideration.

10.4 Anticipating Versus Fixing Problems

One aspect of the DOE approach and its relevance to public perception of the technical competence of the waste management program is whether the basic approach to dealing with problems is through foresight or hindsight. That is, whether the implementing group anticipates how characterization and siting will progress with sufficient accuracy that problems are avoided, or whether problems are corrected as they occur. My own view is that the importance of this question has not been given sufficient recognition in the waste program.

There are political and legal pressures to adopt an anticipatory approach. The DOE must project an attitude of confidence that it knows what it is doing and that there are not significant technical unknowns in its approach. DOE would be unlikely to get public confidence or a license from the Nuclear Regulatory Commission without a detailed plan for managing waste in which solutions to a long list of foreseeable potential problems are presented, and in which the significance of unforeseen problems is minimized. The general agreement that the technical approach must achieve public protection with high confidence requires that uncertainties be tightly bounded.

In spite of these pressures, the feasibility of a fully anticipatory approach is doubtful. Experienced mining engineers I have talked to regarding waste disposal tend to be confident that safe geological disposal is feasible but that many unforeseen problems will need to be solved in the process. Several examples from research and development work on HLW disposal illustrate the kinds of unanticipated problems that can arise. The common aspect of these three examples is that conditions were discovered during construction that were not and probably could not have been anticipated beforehand.

1. The Canadian waste program's underground research laboratory is set in a shaft cut into granite in Pinewa, Manitoba. In the course of digging the shaft, a large fracture was found. Because this fracture would intercept a planned horizontal shaft, the design was altered (the direction of the horizontal shaft was changed) so that the fault would not be encountered. Prior to digging the main vertical shaft, the fault was not identified; by making an appropriate adjustment, the fault was avoided.

2. On May 12, 1987, an accident occurred in the HLW repository under construction in Gorleben, West Germany. One worker was killed and five others injured by a falling support when a ring, placed in the shaft to handle higher-than-expected pressure, failed. It was necessary to fill part of the shaft with concrete after the accident.

3. The Waste Isolation Pilot Plant (WIPP) in New Mexico encountered pockets of pressurized brine in salt thought to be dry.

Events such as these can be used to challenge the competence of those implementing the project. For example, the World Information Service on Energy (Amsterdam) report (Communique 275, June 12, 1987) on the Gorleben accident included the comment that "The cause of this accident was not faulty building material as the construction company first announced but a direct consequence of the geological conditions of which experts had already warned the PTB (Federal Institute for Science and Technology) years ago."

When unforeseen events such as described in these examples occur, the validity of the technical approach and the competence of the risk analysis used to justify the approach are naturally questioned. Conversely, when foreseen events occur (e.g., the failure of the sealing ring on the space shuttle booster), the question is why they weren't prevented. In either case, the technical credibility of the project team suffers.

An additional reason to avoid an approach that puts too much faith in anticipation and pre-planning is that whatever technical approach is initially adopted, the design can be improved by matching the details of implementation to the specifics of the site. Experiments are now going on at the WIPP site to examine the characteristics of various engineering approaches and materials for that particular site.

Claims that accurate predictions can be made for rarely or never-experienced events such as volcanos, large earthquakes, or climate changes are likely to be challenged. While many events or processes receiving analytical attention in the assessment of risks from waste disposal are unlikely to occur, especially during the investigation or operation of a repository, credibility can also be damaged if exaggerated claims are made regarding their risks.

10.5 Suggestions

The technical choices made to date in the HLW program have not depended substantially on a belief that all problems have been anticipated. Geologic disposal is the approach selected by most countries working on HLW disposal; the technical details under consideration vary widely. Geologic disposal has been chosen on the basis of the prevailing technical judgment that this approach can be safely implemented. Similarly, site suitability determinations are based on many factors, the most important of

which are isolation from people and water. These decisions can be explained without promising that every technical problem that might occur has been considered and solved.

The distinction between anticipating that problems encountered in developing a repository can be solved and believing that the details of such problems can be anticipated is of central importance to the maintenance of credibility. While it is necessary for the project team to have confidence that their technical approach is valid, it is also important to avoid a "nothing can go wrong" mindset. Such an attitude is publicly interpreted as arrogance, and failure by DOE or DOE contractors to admit what their technical concerns are is likely to be seen by the public as patronizing. Among the technical community, such an attitude suggests inflexibility and inspires distrust rather than confidence. The limits to what can be anticipated need to be recognized and communicated to the public.