A DISCUSSION OF SOME OF THE PROBLEMS ENCOUNTERED IN COMMUNICATING RISK ASSESSMENTS TO DECISION MAKERS*

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ABSTRACT

Three general areas where problems occur in the attempt to communicate risk assessment information to decisionmakers are examined and discussed. These areas include the language used, the use of uncertainty and probability concepts and the complex nature of risk assessments. Possible resolutions discussed relating to these problems include the use of positive words, more clarity and education.

KEYWORDS: Risk, Assessment, Management, Decisionmaker, Environmental

1. INTRODUCTION

One of the major problems faced daily by scientists in attempting to communicate environmental risks to risk managers is the use of the language. Almost all risk managers lack scientific training or background. There are many important scientific questions that must be addressed in making decisions concerning environmental contaminants. In order to assess the situation, the decision maker needs to understand all the available information. However, there appears to be a gap between those presenting the information concerning environmental contaminants and their resulting risks and those who need to understand the importance of those risks. Some of these gaps are the result of miscommunication and these aspects are discussed and analyzed here.

There are many factors that militate against effective communication. The three that are examined here are: language or the lack of clarity and understanding or the way we speak about risks due to environmental contaminants, the use of concepts such as probability and uncertainty, and the lack of background understanding of the complex quantitative nature of risk analysis.

Our use of language is done often with little thought about how the receiver (listener) decodes and interprets what is heard. We can, unknowingly, make the situation worse or distort information by our choice of words. A simple example of this is in describing the glass half full or half empty.

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There are generally two ways to view reality-- either it is exactly black or white or it is grey. Many risk managers live in a grey world but they perceive it as a precise black or white world. To them the number is either 2.756 or 2.757. Doing something is either safe or it isn't. An environmental contaminant is either harmful or not. But reality is a range of safe, harmful or risky. The effect of an environmental contaminant may vary with concentration, characteristics such as sex, and physical factors such as weather, geology and chemistry. It is in the communication of this probabilistic character of reality that we scientists often fail.

An important characteristic of our probabilistic world is its uncertainty. What do we know for sure? Yet we expect definite answers to the question of whether it is safe, acceptable or whether to regulate! The information and data needed to try and answer these questions is not exact and precise. It is an inherent result of the measurement and estimation process that each quantity has some uncertainty or error. All too often this uncertainty is not communicated with the data, especially when communicated serially through several layers of management.

The discussion that follows is far from an extensive survey of problems encountered in trying to communicate risk assessment information to those who make decisions concerning the regulation of environmental contaminants. The situation is presented from the viewpoint of the environmental scientist. What follows are musings, rambling thoughts and some suggestions for improving this communication link.

2. DOES OUR CHOICE OF WORDS MAKE THE SITUATION WORSE?

All too often we choose words to express the results of risk assessment that have negative connotations. The word risk itself connotes a feeling of danger, insecurity and precariousness. For example, we use such bad sounding words as toxic, hazard, chronic, carcinogen (see a suggested list in Table 1).

Using words that are highly mathematical and technical would seem a poor idea in a society that is characterized by being non-mathematical and even to some degree suspicious and afraid of matters mathematical (after all it takes a modern major general in the Pirates of Penzance to be able to understand matters mathematical). Words such as extrapolate, estimate, guesstimate and statistical are far from reassuring. In fact, they connote the idea that we really don't know what is going on. And for those with some mathematical background, the idea of extrapolating a curve into the unknown is somewhere between dubious and a shocking procedure.

Also used in describing a risk assessment are a lexicon of words meant to reassure but that convey definitive negative feelings. Consider words such as: minimal risk, virtually safe dose, maximum tolerated dose, de minimis (non curat lex or the law does not concern itself with trifles). To many this is like being partly pregnant. Their response to such phraseology is to ask if it is safe or not. At this point the person trying to convey risk assessment information needs to realize that little reassurance or information is being communicated by such phrases.

A major misunderstanding for the decisionmaker is the use of statistical terminology in non-statistical analyses. Statistics require measured data points upon which accepted mathematical analyses are performed. These procedures then produce variances of the measured data, 95% confidence levels based on the data, and error terms. Those involved

Table 1

List of Words Used in Describing a Risk Assessment That Convey Positive or Good and Negative or Bad Connotations

<u>Bad Connotation, Bad Sounding or Negative Words</u>

absolutely	interpretation
acute	judgement
always	law suit
anxiety	lifetime exposure
average	maximum tolerated dose
below regulatory concern	mimimal risk
carcinogen	never
causality	nuclear(e.g. NMR to MR)
controversy	perilous
chancy	poisonous
chronic	precarious
cost	probability
danger	provocation
decision	radiation
di minimis	regulations
dispute	risky
estimation (over- or under-)	scientific
evaluation	statistical
extrapolate	statistics
fear	technical
guesstimate	toxic
hazardous)	uncertainty
insecure	unsafe
	virtually safe dose

<u>Good Connotations, Good Sounding Words, Positive Meaning or Connotation</u>

acceptable	prevention
admissible	reliable
assurance	responsible
benefit	safety
choice	security
confidence (as in 95% confidence level)	stable
common sense	strength
dependable	threshold
faith	tolerable
free	truth
freedom	trust
health	unforced
intact	voluntary
no effect	willing
predictable	zero risk

in risk analyses have borrowed the terminology and applied it to hypothetical data sets derived from some arbitrarily chosen mathematically chosen model. This mistakenly gives the decisionmaker the false confidence that he is dealing with actual statistical data from which the true number can be determined.

A common mistake is to express risk assessments with absolute words.

Using words like always and never (e.g., the toxic material in the town dump will never reach your well), ultimately leads to suspicion as most people feel that almost anything is possible. The decisionmaker is at one extreme thinking that all health effects are due to some pollutant in his air or drinking water. Expressing a risk assessment at the other extreme by saying it isn't possible does little to allay fears.

Often the very words that have a negative character are used too freely. Constant use of words like anxiety, fear, cancer, controversy, radiation and hazard should be held to a minimum. The proper use of these words should not be avoided or minimized, the point is to tell the whole truth and nothing but the truth.

Society is full or misrepresentations, myths and lies. Ideas such as cancer is always fatal, the nuclear reactor or town dump will not pollute the river and dioxin always does bad things to humans, feed what may be an already high level of fear, anxiety and guilt. Once an official has made the mistake of propagating a lie, he is stuck with these emotions and will likely continue to convey them (see Reference 1 for a recent discussion of the phenomena of lying).

Sometimes we use language to seduce us to accept the unthinkable. In the area of nuclear devices we use words like accident, overkill and arms control to mask a highly deadly force. In risk assessment similarly we have language such as cases averted, excess cases and population risk that are used which often mask the real meaning.

Too often the question of whether a situation is safe arises too late for an education process to be possible. Statements that the level of risk is low (even of the order of 10-6 per lifetime) are not reassuring. The truth must be made clear as soon as it is known or any trust will be destroyed. This trust will likely be best built at the local level since ultimately the local community will likely be the one to deal with risk management.

In order to minimize fear, anxiety and misunderstanding, language should be used that provides a more balanced picture. It might be tempting to misuse words to deceive, but the responsible official seeks to convey the truth. The objective is to avoid words with an unnecessary negative connotation. Examples of words with a positive connotation are given in table 1. Instead of technical jargon such as estimate, why not say this is our knowledge or understanding. It sounds better to say that 'we determined that' instead of 'we estimate that' or 'we conclude that.'

The above discussion is admittedly short and far from comprehensive. However, if those doing and communicating risk assessment information would think some about the words used to express the results, a more balanced picture can be conveyed and some trust can be built.

3. COMMUNICATING THE PROBABILISTIC ASPECT OF RISK ASSESSMENT

We live in a probabilistic world where very little, if anything, is totally certain. Where you are, what you do, when you do it are all things that it may not be possible to describe with exact precision. Why then is it so difficult to comprehend what a probability of one in a million risk is like? What is the response to the question, "Well, is it safe, and if so how safe?" To get some idea of the dimension of this situation first consider the role of probability in our day-to-day existance. Later in this section possible responses to this question will be discussed.

Some of our information on non-fatal probabilities are handled in a qualitative way. Whether our cold will get better or worse will determine whether we go to work today. What is the likelihood that the car will start, the boss will be late? We take risks based on our judgement of the probabilities of these and other events. Table 2 is a short compilation of daily probabilistic choices most of us make and take for granted.

We are exposed to probabilistic information daily. The weatherman tells us that there is a 30% possibility of rain tomorrow or our boss tells us that the chances of our proposal being accepted are one in four. The stock market involves the use of probabilities based on assets, sales, past performance, size, etc. What are the odds that it will go up or down tomorrow? Our insurance premiums are based on the odds of us dying given our age, sex and general health. These estimates are all based on experience. For example, physicians are used to telling us that the odds of the hernia getting worse may be 50% now and higher in the

Table 2

Common Daily Probabilistic Choices

Category	Probability
Weatherman (forecast probabilities)	10% 80%
Bus or train being late	
5 minutes	50%
10 minutes	40%
20 minutes	5%
30 minutes	1%
Airplane	
Takeoff or arrival being late	50%
Medical probabilities	
Inheritable traits (color blindness, Huntington's Chorea, diabetes)	25%
Heart trouble	40%
Breast cancer	20%
Lung cancer	
Smoker (3 packs a day)	60%
Non-smoker	5%
Alarm clock failure	1/365
Car failing to start	1/365
Gambling	
Poker	1/52
Roulette	1/38
Dice	1/6
Lotteries (winning jackpot)	1×10^6

future, or the chance that the hernia will strangulate are 5% over a lifetime. An EKG stress test comes complete with a consent form that estimates the risk of episodes or transient lightheadedness, fainting, chest discomfort, leg cramps of 2 to 3 per 10,000. The chance of a pack a day cigarette smoker getting lung cancer is about 10%.

Even if we know that the odds are against us people generally continue to act as if that was not true. Anyone who has thought about gambling such as the roulette wheel, dice and card games know that the house always wins in the long run.

In making decisions on the quality of life versus death, pulling the plug, or expensive heroic measures, we have to make judgments that involve qualitative measures. The odds of having a child with birth defects increase with the age of the parent. The parents of a child born with birth defects must decide how far they should go in giving medical attention? Should their response be based on medical, ethical or financial information, or on all? How much information in the form of quantitative values do we need for everyday decisions? (for driving, medical treatment, eating, sleeping, working, etc.)

Another problem the health scientist encounters in trying to communicate with decisionmakers is establishing what an adverse effect is and at what level it occurs. All decisionmakers easily grasp that carcinogenicity and death are adverse effects. It is hard to convince decisionmakers that decreases in nerve conduction velocity, or in increase throughout the general population in both diastolic and systolic blood pressure are adverse. There are two classes of toxicological endpoints. The first is the traditional measured endpoint from an experimental group or cohort. The second is these changes produced in the general population.

Changes noted in the general population are major health effects. Most decisionmakers cannot perceive this. Examples of this are the 20 years it has taken to convince people of the causal association between lung cancer and cigarette smoking. A second example is the slight but statistically significant increase in blood pressure as a result of lead exposure. If the blood pressure of people increases with small increases in blood lead levels, then many tens of thousands of deaths, strokes and myocardial infarctions could be avoided by controlling lead exposure.

Subtle traditional toxic endpoints produced in the human population such as enzyme changes, increased red blood cell fragility, or decreased immune system function are hard to determine exactly when they go from statistically significant changes to adverse effects.

We use a limited number of heuristic principles to analyze seemingly complex daily problems. However, the probability or sample size appear to views on probability are dependent on their life experiences and not on reason or logic.

Since the use of probability is a learned skill for the public, the decision maker or anyone, more attention needs to be placed on how to educate in this area. We need to expand peoples' numerical abilities beyond one in a thousand or perhaps into the region of one in a million. This latter level is of the order of the lifetime background risk of fatality due to natural occurrences such as lighting, tornadoes, cyclones, earthquakes, and bee stings.

If risk assessment/risk management is to have any usefulness to the decision maker, the meaning of 10^{-5}/lifetime or 10^{-6}/lifetime must be communicated in a way to be useful next to the social, psychological (perceptional), political and economic consequences of a potential environmental contaminant.

4. UNCERTAINTY

The most straightforward kind of uncertainty is that involving the measurement of the facts themselves. Any measurement contains random and systematic errors. In measuring the length of the table, the yardstick may be worn so that it is less than one yard. This is an example of a bias or systematic error. The smallest measure on the yardstick is a limit to the smallest length difference that can be measured. If several people use the same yardstick to measure the length of the same table, there will be a range of values related to the smalles measure on the yardstick. This latter range is representative of random error or uncertainty.

Another contribution to help the understanding of uncertainty is to point out where we use this concept in our everyday lives For example, if the speed limit is 55 mph, do all the cars go that fast as an upper limit? We are all aware of a range of speeds around that value due to differences in what our speedometers read, lack of care to maintain the speed or a deliberate pushing of the limit. In any case, most people are aware of an uncertainty of a few mph. Another example of use of uncertainty is when to show up for an appointment or at a dinner party. In some circles it is common knowledge to show up 15 minutes or 30 minutes after the appointed hour for a dinner party. In any case we all have a range of times we find acceptable for being 'late'.

There are many kinds of uncertainty besides the quantitative error related to the measurement and estimation. There can be uncertainty about what people think about the facts and the future consequences of present decisions (3). Other kinds of uncertainties include questions like 'have we included all events and outcomes' and 'is the description mutually exclusive?' (4). If a model is used, there is uncertainty about how well it represents reality.

Any measurement of environmental parameters likewise will contain some uncertainty. In addition, extrapolations of these measurements of specific values to general predictions increases the uncertainties. For example, using the measurements in 1,000 drinking water supplies to estimate the concentrations in all 60,000 public drinking water supplies will involve uncertainty. These kinds of uncertainties are inherent in the measurement system itself and are an inescapable part of reality. However the magnitude of these uncertainties can be estimated.

Communicating the inherent measurement and estimating quantitative uncertainties is often a difficult and frustrating task. All too often, the caveats describing the uncertainty in a standard of level are lost in the use of the number and the number itself is quoted without these caveats. A partial solution to this problem is to express all background information as ranges, reflective of the uncertainty, and only give a single number as the final standard.

One general misunderstanding of the idea of uncertainty is represented by those who want to get more data to reduce the uncertainty. In some cases this is unnecessary. If a lifetime risk estimate were, for example, in the range of 0.00001 and 0.01 extra health effects, most people would agree that this is a quite small value and may not require a regulation in spite of the uncertainty of three orders of magnitude or a factor of 1,000.

Besides trying to educate decisionmakers about the value of knowing the uncertainty quantitatively, the way in which numerical estimates are quoted should be considered. In most high school mathematics courses we all learn about significant figures. With the advent of the hand-held calculator, we can calculate a number to many significant figures. But if the estimation is a range of 0.001 to 100, it makes little sense to quote a single value of 1.239671 as we too often do.

The development of a health-related regulation or standard is a legal and political, as well as scientific, endeavor that requires specific language and in most cases a specific number. Enforcement and the legal process demand a specific numerical value against which to test the situation. But the reality of existing data involves a wide range of uncertainty in any measured or estimated value. Thus there is a conflict between reality and the legal process.

The objective of determining quantitatively the uncertainty in risk assessment information is to characterize reality. Not knowing how far off an estimate can be may be just as bad as not knowing the number at all. An estimate of cost somewhere in the range of $1 to $10,000,000 is very different than one in the range of $100 to $500. The latter case involves more certainty and is likely to be more useful.

5. CAN DIFFERENT RISKS BE COMPARED?

As a way of getting an understanding of what a risk 10^{-4}/lifetime, 10^{-5}/lifetime and 10^{-6}/lifetime, it could be compared to other risks. However, all risks do not have the same characteristics and certain complexities make interpretation difficult. Comparing the risks of ingesting or inhaling an environmental contaminant to that of hang gliding, rock climbing or insect bites raises the issue of which is voluntary or involuntary. Other complexities that make comparison of risks difficult include: natural/manmade, luxury/necessity, old/new, catastrophic/ordinary (5). Because of these complexities it is seldom possible to get a good understanding of a given risk level by comparing it to other risks of the same frequency. Thus, the understanding of a given risk must be done on a case-by-case basis.

Assessing the risk due to an environmental contaminant is only part of the larger picture the decisionmaker is faced with. In communicating risk information we must realize that it is only part of the total picture. Even in the risk analysis itself, it is a danger to think too narrowly. For example, usually just the individual risk rate is not enough information. Also needed are the population risk values, the background risk rate and the risk rate from other contaminants.

Also, the decisionmaker, in an effort to get the 'big picture', can be overwhelmed with detail. There is little problem today in getting detailed information and lots of it. The problem is to limit that going to the decisionmaker to what is pertinent. The risk assessor must organize and display data and information in a concise way that is understandable by the decisionmaker.

6. ARE THERE LIMITS OR BOUNDS ON NUMERICAL COMPREHENSION?

Can we understand the probability as small as 1 in 100, 1 in 1000, 1 in 10,000, ... etc? Is there a point in this sequence beyond which we cannot comprehend? The odds of winning lotteries or giveaways are often listed and can be even less than those listed above. Yet many people take the chance. is this a calculated risk? Do we really understand the risk of 1 in 10,000?

There is a limit to numerical experience that is culturally based. In some primative societies the counting sequence is 1,2,3, infinity. That is, a number larger than 3 is infinite -- all numbers larger than 3 are infinite or beyond comprehension. By analogy, can we understand and make decisions based on risks of 1 in 10, 1 in 100 and 1 in 1,000, but beyond that all risks are called small or negligible? The limits to our understanding of numerical estimates are similarly culturally limited.

Many of us resist estimating times, distances or anything quantitative. It is a well known procedure to an attorney. When asked how often a witness went to the park this year, the response might be that he doesn't know. The attorney then says is it 1,2,10, 100, more than 100? Finally the witness responds, say not more than 100. The attorney then tries to narrow the estimate. We all have this kind of information, but seldom think quantitatively, or need to.

We usually respond negatively to quantitative questions. For example, can you name 20 birds? Your first response is likely, no. But think for a minute and you will soon name more than 20 birds easily. Why the resistance? Likely it is part of our education. We somehow come out of school with a negative view of mathematics and a dislike for word problems (which many of the estimation problems in environmental regulation are). It is this fear of mathematics that leads to our resistance to quantitate or estimate.

The limits to our abilities to handle numerical or quantitative estimates is thus limited by our culture and experience. The only way to alter this situation is through education.

7. DISCUSSION AND CONCLUSION

The three general areas discussed are shown in Table 3, with some possible solutions. The thoughts and ideas cover a range from the specific to the general.

In the area of communicating information concerning the risk due to the environmental contaminants, perhaps the easiest adjustment is to use positive language. For example, use words such as 'range of certainty', 'benefit', and 'predictable', instead of 'uncertainty', 'risk' and 'probability'.

However, these ideas and concepts must be included in any presentation, discussion or analysis. Whether the true risk is called 'range of certainty'. 'uncertainty' or 'error', it is reality and to ignore this leaves the decisionmaker with a skewed and simplistic perspective about what is really known.

To transmit the complete picture of scientific and technical knowledge about an environmental contaminant requires some education in the area of quantitative analysis. Whether it is liked or not, the decision maker needs the quantitative tool called probability and statistics. However these concepts are exciting and interesting when properly presented. As pointed out earlier, we use these concepts in our every day life from weather to medicine. What is needed is to put a clear

Table 3

General Problems in Communicating Risk Assessment Information to Regulatory Decisionmakers and Some Possible Solutions.

Communicate Problem	Potential Solution
language	use words with positive connotation
complex nature of risk assessment information	more clarity and reality in scientific and technical information presented (e.g., use uncertainty)
lack of understanding of concepts such as uncertainty and probabilty	education -- schools -- news media -- use everyday examples

picture of these ideas about reality into the analysis of the risk resulting from environmental contaminants.

Thus, it is the task of the scientist (technical person) to introduce and explain to the decision maker concepts in toxicology, chemistry, meterology, geology and physics, some grasp of Greek prefixes, orders of magnitude and the reality of measurement. These must be done in as positive a manner as is possible because the non-technical decision maker must weigh these considerations when making public policy decisions. Reminding the decision maker of reality is one of the tasks we scientists meet to perform regularly. Using positive ideas such as range of uncertainty and relating that to real world situations to help quantify the range is the step in the education process most often neglected.

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COMMUNICATING INFORMATION TO RISK MANAGERS:

THE INTERACTIVE PHASE[1]

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ABSTRACT

Information display and presentation is one of the most serious problems standing in the way of more extensive and effective use of risk analysis. Most risk analyses as presented do not clear minimal display requirements; viz. that the user adequately understands what the analysis can tell him that is useful for his purposes, and this is why risk analysis so often fails as a practical aid to decision makers. Information communication has two phases: "basic," where the essential information is presented in a preplanned set report; and "interactive," where the user calls up additional information as his interest dictates. This paper discusses methods for performing the interactive phase, especially through interactive computers, using novel concepts, such as macro modeling, user override, and plural analysis. The communication methodology is exercised in the context of two cases: a PRA adapted to an NRC regulatory decision on whether to require a costly backfit at an operating reactor; and a computer aid for making lab safety decision, based on a complex risk analysis model and data base.

KEY WORDS: Risk management, information communication, interactive computers, decision aids

1. INTRODUCTION

An issue of considerable importance to risk analysts and other decision scientists is how to get across, economically and effectively, the fruits of their research efforts to decision makers in government and elsewhere. Communicating risk management information to a decision maker, such as a regulator, usually has two distinct phases

The first is the "basic phase," wherein the communicator sets forth a minimum set of information that he is satisfied the user will want to know, and which he can prepare ahead of time. This usually takes the form of a basic report, which is typically a written document or a formal briefing. We have addressed elsewhere methods for enhancing this phase

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which has, in any case, attracted most research attention to date (Brown & Ulvila, 1985).

The second is the "interactive phase," which conveys optional information in response to user needs or interests that emerge after the basic phase. In many cases, this is the more important part of the communication process and may account for the bulk of the time the user devotes to informing himself about the problem at hand. The basic set report may simply play the role of launching a dialogue between user and researcher, which carries the main burden of communication.

The purpose of this paper is to review some approaches to enhancing this latter interactive phase. The object is for the user, with a modest expenditure of effort, to end up understanding what a given body of research information (such as a risk analysis study) has to say that is useful for his purposes (e.g., to make or defend a regulatory decision). The work we will discuss is part of a larger research program on communicating with decision makers, supported largely by the National Science Foundation and by the Nuclear Regulatory Commission. The current findings are summarized in Brown (1985b), which includes references to more detailed project reports.

The objectives of the interactive phase of communication are not essentially distinct from those of the basic phase. However, there are some distinctive thrusts. The prime function of the basic phase is to present findings of the research which are of direct interest to the user (e.g., the probable implications of adopting one action or another); as well as their most obviously relevant determinants (such as baseline risk, for a risk management decision). In the interactive phase, however, one may wish to focus primarily on other facets: "making the black box transparent" (i.e., understanding the argument which drives the main findings); pooling the findings with alternative perspectives the user may have access to on the same issue (including his personal judgment); and integrating the issues addressed with other considerations (e.g., political), which he will need to take into account before he makes a decision.

2. A CASE ILLUSTRATED APPROACH

2.1 Context

We have been developing some techniques, computer-oriented in the main, to help in the interactive phase and have begun to give them operational implementation, in the form of two software prototypes developed for live risk management problems. The first of these is intended to support a one-off regulatory decision for NRC, the other is to support repetitive lab safety decisions at a local level for EPA. For concreteness, we will discuss our ideas in the context of these two cases. Neither of them, it should be pointed out, has yet been used to make real decisions, though both have been partially field tested and have received favorable responses from users and the research community. The technology is certainly still immature.

The first case relates to a decision by the Nuclear Regulatory Commission, specifically the Commissioners acting on the advice of Office Directors, on whether to require a certain "venting" backfit at particular operating reactors (Brown & Ulvila, 1985).

The research information to be communicated, at least in part, deals primarily with the current level of "baseline" risk at the plant, reduction in the risk to be attributed to the proposed backfit, and the cost of installing the backfit. The issues have, in the past, been the subject of major probabilistic risk assessment and related studies, whose relevant implications the decision makers wish to learn.

They have received a basic report (presented in Brown & Ulvila, 1985, as a "sample decision support paper") whose central finding is captured in Figure 1. The rest of the basic report is essentially a clarification and a summary of the rationale behind this finding. The primary message is that the proposed venting backfit has a modestly positive net benefit, if risk reduction is valued at $1,000 per man-rem averted, but there is major uncertainty about this assessment, due mainly to uncertainty in the risk reduction side.

2.2 The Macro Model

At the core of our approach is the "macro model," which is a deceptively simple idea, developed some ten years ago in the context of evaluating nuclear safeguards (Brown & Feuerwerger, 1978). It consists essentially of expressing a target variable of real interest to the user (in this case the net dollar benefit of requiring a venting backfit) as a function of a small number of its high-level determinants. These are few enough in number, typically no more than a score, that the user can work comfortably with them, at a level of aggregation that he can readily relate to. (Figure 1, in fact, shows an extreme form of macro model in that net benefit is expressed as a two term function--the difference between benefit and cost.)

Usually a lower level of aggregation is more useful. In this case, for example, backfit net benefit was expressed as a function of: baseline core melt probability per year; remaining plant life; baseline risks, given core melt (onsite man-rems, offsite and onsite property damage); industry and NRC costs; impact on each of the above due to backfit; and the dollar equivalent of a man-rem averted. (This macro model will be an approximation, but it could be turned into an identity by using residual variables, such as "any other costs" or "any other benefits.") Such a macro model can be used both as an organizing principle for designing and analyzing total research effort, or for exploring the implications of a given research effort, as in the interactive communication phase.

The macro model is usually not obtained as a summary distillation from an existing and finely grained "micro" model, however, since the latter is typically not designed to produce exactly the target variable best suited to the user. Typically, "feeder" models (or analyses) are needed to organize available research material into the inputs required for the macro model; or "bridging" models (or analyses) to adapt the output of already existing models (such as PRAs) into input for the macro model. This need for adaptation was certainly true of the case study in question. For example, available PRAs addressed only the probability of a core melt that was internally initiated. Externally initiated events (such as station blackout) needed to be addressed from some other source, in order to come up with an overall probability of core melt (one of the macro inputs).

Figure 2 shows the main macro model display developed for the backfit decision, as displayed on an interactive PC screen. The complete computerized aid is described in Ulvila and Thompson (1985).

For each of the input variables cited above, there is an assessment consisting of a median estimate and a 90% uncertainty range about where an "ideal" estimate might lie. (The meaning of this concept is discussed in

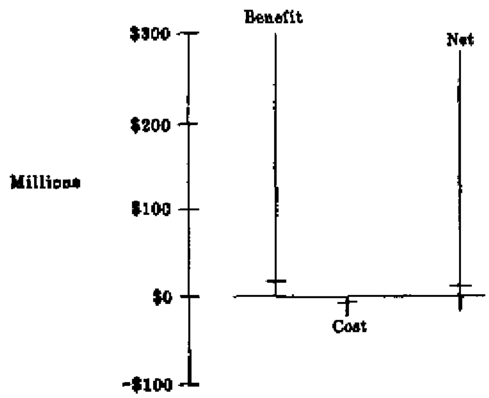

Figure 1

Cost-Benefit of Venting: Expectation and Assessment Uncertainty (90% Range)

Brown (1985a)). The screen also displays implication of these assessments for the target assessment, expressed as a mean and 90% range (on the arguable grounds that, while the median is more readily assessed, the mean is a more useful performance measure). Some intermediate calculations of potential interest are also displayed, such as mean inputs, benefits and costs. The user of the macro model can set (or change) any of the input, and have immediately displayed impact on output and intermediate assessments.

Although structurally simple, the development of this screen requires non-trivial attention to formulation and display from the point of view of user friendliness and to the computational algorithms of uncertainty propagation. Because the format of these assessments was selected for ease of judgmental assessment and verification by the user, they required some bridging with PRA material.

VENTING BACKFIT: INPUTS AND IMPLIED NET BENEFIT

	Baseline			Backfit Impact		
	Median	90% Ratios	Mean	Median	90% Ratios	Mean
RISKS:				Reduction Factors		
Core Melt/yr (x10E-4)	.300	.100-10.0	.749	.700	.140-1.35	.653
Plant life: 30 yrs.						
Risks Given Core Melt:						
Offsite man-rems (M)	20.0	.010-3.00	23.7	.500	.800-1.90	.564
$/man-rem: 1000						
Offsite property ($ B)	1.00	.000-6.00	1.74	.500	.800-1.90	.564
Onsite property ($ B)	4.00	.250-2.50	4.55	.980	.990-1.01	.980
COSTS:						
Industry implementation cost ($ M)				3.00	.330-5.00	4.84
NRC implementation cost ($ M)				.200	.250-5.00	.320

NET BENEFIT:	Benefit	- Cost	= Net
Means	+ 40.6 M	- $ 5.1 M	= $ 35.4 M
90% Range	1.1 - 168.9	1.1 - 15.5	13.4-- 159.6

F2 INPUT	F4 INTER	F6 OUTPUT	F1 CALC-1	F3 CALC-2	F5 CALC-3

Figure 2

Macro Model Screen for Backfit Decision

2.3 Plural Analysis

This simple macro model device can be used to perform several distinguishable functions in the interactive communication phase. In particular, it can be used to make transparent the "black box" of the underlying PRA and other research, by showing how the target assessment is related to key determinants.

However, it can also perform more ambitious tasks having to do with integrating the material being communicated with alternative perspectives on the same issues, which we refer to as "plural analysis" (Brown & Lindley, 1982, 1985). For example, it can enable the user to splice in his own judgment (or any other information he may have) by overriding the input assessments he wishes to take issue with (or to test the sensitivity of the output to). It can also be used to help the user pool information represented by the macro model with alternative models and assessments of the same target variable, using the pooling techniques of plural analysis. In particular, it provides a quantified measure of confidence in findings, in the form of a 90% uncertainty range, which can be made to reflect the user's personal confidence in the main areas of analysis (through input 90% ranges). This can be used in weighting alternative assessments (including this one) for pooling purposes.

2.4 Multi-Level User Override

The second case study, dealing with a communication aid for safety decisions, takes the "user override" idea a significant stage further. The underlying research material to be communicated in this case was a very large "micro model," consisting of an extensive technical data base, integrated with a complex risk analysis model and multiattribute utility model. In principle, it will take any chemical substance subjected to a laboratory operation and calculate the relative value of adopting one safety measure or another. The problem with this, as with any general-purpose decision aid designed in advance of any particular decision situation, is that when a decision situation actually arises, the decision aid never exactly fits. It needs to be adapted to the special circumstances. In particular, the substance-operation-safety measure combination may not have been anticipated; and the assessments incorporated in the large "micro" model may not be based on the most relevant information that may then be currently available.

To attempt to address this problem and introduce the necessary flexibility, we developed an elaborate user interface which allowed the user to inspect and override variables at any of a large number of levels within the micro model. The main user override features of the aid are shown in Figure 3 (for a detailed description, see Mendez, et al., 1984a,b). The boxes whose titles are underlined are inputs; those in capitals are outputs; and those which are both capitalized and underlined can be both inputs and outputs. These are the user override variables.

For example, if the substance being analyzed is not on the stored list, a close analogy can be selected (first column of boxes), and its chemical properties displayed (in the second column). These can then be adjusted, in the override mode, for any judged differences and carried through in the model's remaining calculations. Alternatively, at an intermediate level, the user might observe that the calculated probability of upset does not jibe with his experience at this facility, and he may override it. Yet again, the relevant cost of using a fume hood as a safety measure may be higher than the standard cost stored in the data base, because all available hoods are already being used, and so the opportunity cost of a hood is abnormally high. The user may even wish to override stored value judgments; for example, he may not wish to use $1

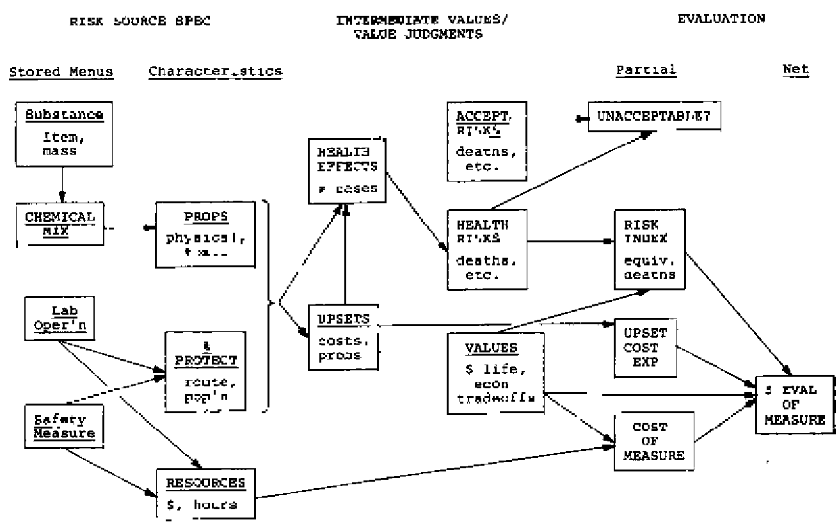

Figure 3

A User Override Model to Evaluate Lab Safety Measures

million as the value of a human life or give the health of laboratory workers only 1/10 of the weight of the health of the general public (both of which were default parameters).

In a sense, this user override aid is a generalization of the macro model. It can be thought of as a macro model which can be specified at varying levels of depth, and any of the uses to which the macro model can be put, this override can be put to also. For example, it can be used to merge plural analyses, including splicing in the user's independent judgment, at any point in the model where input can be supplied.

3. CONCLUSION

3.1 Design of an Information Management System

Figure 4 recapitulates the various elements discussed above for a man-model information management system, for the interactive communication phase. It shows how the primary data base, which may be one or more extensive studies and/or models is successively transformed and reduced into a form where it directly answers the user's question. More important, it shows how the user's judgment (and other data he has access to) can be introduced at varying points in the transformation in a dynamic interactive fashion; such that at the end of the interactive phase the user has extracted from (and incorporated into) the research material being communicated, what he needs to make a balanced and informed decision.

3.2 Institutional Issues of Interactive Communication

We have talked as if our information communication tools were to be used directly by the decision maker/user to selectively dig out and absorb

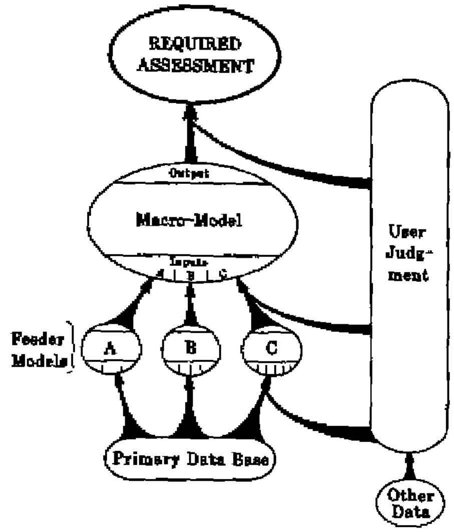

Figure 4

An Information Management System

what he needs from the research material to be communicated. In fact, we believe that a quite separable role needs to be played, that of the "communicator," who mediates between the user and researcher.

For the foreseeable future, we see the user needing to interact directly with the communicator, who answer ... user's questions using whatever data and tools he has available, ... ing, but certainly not limited to, the computer-oriented aids we have been discussing. Indeed, a sufficiently skilled and well-informed communicator would not need any aids at all to be effective, but could draw directly on his own knowledge. However, we have not yet seen his likes, and he would need quite unusual talent, training and knowledge. Nor have we seen a user with sufficient training and leisure to access the data directly or through computer-aided tools, without the mediation of as competent a communicator as he can find.

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