UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D C 20555

December 16, 1997

The Honorable Shirley Ann Jackson
Chairman
U S Nuclear Regulatory Commission
Washington, D C 20555-0001

Dear Chairman Jackson

SUBJECT TREATMENT OF UNCERTAINTIES VERSUS POINT VALUES IN THE PRA-RELATED DECISIONMAKING PROCESS

During the 443rd, 444th, 446th, and 447th meetings of the Advisory Committee on Reactor Safeguards, July 9-11, September 3-5, November 6-7, and December 3-6, 1997, respectively, we met with representatives of the NRC staff to discuss issues included in the Staff Requirements Memorandum dated May 27, 1997, regarding the use of uncertainty versus point values in the PRA-related decisionmaking process (Reference 1) Our Subcommittee on Reliability and Probabilistic Risk Assessment (RPRA) met with the staff and industry representatives to discuss these matters on July 7, August 28, October 21-22, and November 12-13, 1997

Background

Uncertainty has always been of concern to nuclear power regulators As early as 1956, Willard F Libby, Acting Chairman of the Atomic Energy Commission (AEC), wrote to the Congressional Joint Committee on Atomic Energy that "it is incumbent upon the new industry and the Government to make every effort to recognize every possible event or series of events which could result in the release of unsafe amounts of radioactive material to the surroundings and to take all steps necessary to reduce to a reasonable minimum the probability that such events will occur in a manner causing serious overexposure to the public " (Reference 2)

Even though Dr Libby used the word "probability," about 20 years would pass before systematic calculations of probabilities would be produced for the "possible event or series of events" to which he referred The "reasonable minimum" of the unquantified probability that was achieved at that time was attained through the development and application of the concepts of defense in depth and safety margins

Defense in depth is advocated in numerous documents as the principal means of controlling the (still unquantified) probability of accidents For example, during the 1971 hearings on emergency core cooling, the AEC staff stated "The safety goal, therefore, is the prevention of exposure of people to this radioactivity This goal can be achieved with a high degree of assurance, *although not perfectly* [emphasis added], by use of the concept of defense in depth The three separate lines of the defense in depth provided for power reactors are considered appropriate to reduce to an acceptable value the probability and potential consequences of radioactive releases " (Reference 3)

Although the approaches of defense in depth and safety margins have served the industry well from the safety perspective, they were intended to be conservative and, as implemented today, they impose a heavy regulatory burden The level of safety was not quantified The first call for a more rational approach to regulation based on improved understanding of risk came in 1967 from F Reginald Farmer (Reference 4) of the United Kingdom Atomic Energy Authority The Reactor Safety Study (WASH-1400) (Reference 5) soon followed in 1975 Not surprisingly, the WASH-1400 study itself proved to be conservative in some areas, e g , the analysis of the containment, and nonconservative in others, e g , the analysis of earthquakes and fires There has been tremendous progress in our understanding of the risks from nuclear power plants since that study (a history of PRA developments since WASH-1400 is given in Reference 6)

Realizing that the availability of risk numbers made it possible to reexamine the question of how safe is safe enough, the Commission issued the safety goal policy in 1986 (Reference 7) The recognition that uncertainties had to be dealt with is reflected in the following three statements from the policy statement

<u>Statement I</u> "It is the Commission's intent that the risks from all the various initiating mechanisms be taken into account to the best of the capability of current evaluation techniques."

<u>Statement II</u> "To the extent practicable, the Commission intends to ensure that the quantitative techniques used for regulatory decisionmaking take into account the potential uncertainties that exist so that an estimate can be made on the confidence level to be ascribed to the quantitative results "

<u>Statement III</u> "The Commission has adopted the use of mean estimates for the purposes of implementing the quantitative objectives of this safety goal policy "

The Commission's safety goals were derived from societal considerations, i e , independent of the PRA state of the art Even though they were expressed both qualitatively and quantitatively, it was clear that the Commission did not intend to simply compare a PRA "point estimate" (however it was defined) with the numerical goals

The Issue

As noted above, the numerical estimates that PRAs produce have been scrutinized to an extraordinary degree since the early days of WASH-1400 Sometimes the debate regarding the accuracy of these numbers detracts from the intended use of PRA

It is not the intent to regulate on the basis of risk estimates alone (thus, "risk-informed" regulation) The objective is to gain enough confidence in the numerical probabilities of a set of accident scenarios so that the traditional approaches (defense in depth and safety margins) that have already been applied to this set can be better managed This means either relaxing some existing requirements, if proven burdensome and non-contributing to risk reduction, or adding new requirements, if the traditional approaches have not covered some detrimental events

The preceding discussion suggests that the question regarding the quality of PRA results ought not to be an absolute one, but, rather, a comparative one Therefore, we offer the following observation

<u>Observation 1</u>

When PRA results and insights are proposed to be used in the regulatory process, the question to be asked should be To what degree is there confidence that the use of PRA results and insights will improve on the existing regulatory system for the problem of interest?

The words "PRA results and insights" include the set of dominant scenarios to risk (or core damage, as the case may be), as well as an assessment of the uncertainties regarding the frequencies of these scenarios The utilization of PRA results and insights depends on our confidence that their use will improve the regulations in accordance with the Commission's vision It is definitely not a case of PRA versus the traditional approach

In Observation 1, the key words are "will improve " There is improvement when the regulations contribute to the safe and efficient use of nuclear materials, as per the recently articulated vision of the Commission "In implementation of its mission, Nuclear Regulatory Commission actions enable the Nation to safely and efficiently use nuclear materials " (Reference 8)

Uncertainties

As our brief historical review has demonstrated, the uncertainties regarding off-normal events and incidents in nuclear power plants have been of concern since the early days of reactor regulation In the early seventies, quantifying the uncertainties was synonymous with developing probability distributions for the failure rates and the frequencies of accident initiators This explicit quantification of uncertainties posed a new problem to safety analysts They soon discovered that the interpretation of the concept of probability was controversial among mathematicians Several schools of thought were available, of which the frequentist and the Bayesian schools were dominant When the nuclear debate was heating up in the mid-seventies, the analysts were reluctant to get involved in an additional controversy

This attitude, although understandable in the context of the times, was unfortunate, because it led to confusion and the perception that uncertainty analysis was controversial and to be avoided It also led to some circumlocutions For example, the WASH-1400 treatment of failure rates is purely Bayesian, yet that voluminous report does not acknowledge this fact explicitly Similarly, the NUREG-1150 studies (Reference 9) claimed to elicit "weighting factors" from the experts, rather than admit that they were eliciting probabilities Although "officially," both frequentist and Bayesian viewpoints were equally valid, no PRA had been done using frequentist methods because it cannot be done Industry-sponsored PRAs, however, have readily acknowledged using Bayesian methods in an explicit way (Reference 10)

It is now known that uncertainties in failure rates and other parameters appearing in PRA can be quantified via probability distributions using available generic and plant-specific data and appropriate Bayesian methods The propagation of these distributions through the PRA logic diagrams is straightforward using standard computer packages We believe that there is no excuse for failing to do an uncertainty analysis on the parameters of the PRA models Therefore, we offer the following observation

> <u>Observation 2</u>
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> The Bayesian interpretation of probability provides the appropriate framework for PRA Probability distributions for the parameters of PRA models, e g , failure rates, should be developed using all available evidence and propagated to produce the probability distribution of the quantity of interest, e g , core damage frequency (CDF) and large, early release frequency (LERF)

Since regulators must confront uncertainties, it is evident that, if PRA is to be used as in our Observation 1, the probability distributions of Observation 2 must be derived Anything less does not represent what is actually known about these failure rates This brings up the issue of "point estimates," for which we offer the following observation

Observation 3.

> The only "point estimates" that are unambiguously defined are those that are summary measures of a probability distribution, e g , the mean value, the median value, and various percentile values

Ill-defined "point estimates," such as "best estimates," have limited utility Point estimates are valuable for screening purposes after a convincing case has been made that the uncertainties have been handled appropriately, e g , they are either negligible or have been bounded In fact, the use of such point values is an important tool in screening the thousands of minimal cut sets that a PRA produces Such use, however, should be followed by a rigorous uncertainty analysis of the dominant sequences

The uncertainties of interest in reactor regulation have been termed "state-of-knowledge" uncertainties (Reference 11) or, more recently, "epistemic" uncertainties (References 12, 13) The parameter uncertainties that are referred to in Observation 2 are only a part of the total epistemic uncertainties Uncertainties resulting from model assumptions and approximations are also epistemic and more difficult to quantify Examples would include models used for evaluating severe accident phenomena in Level II PRAs

Model uncertainty is the key to any use of PRA results When events or processes are modeled poorly or not at all, there is uncertainty that has not been quantified, in the sense that it is not part of the probability distributions produced by propagating parameter uncertainties The fact that uncertainty is not quantified does not mean, however, that nothing is known about it The PRA structure provides a good framework within which these uncertainties can be assessed qualitatively through sensitivity analyses or other means (see, for example, Reference 14) These uncertainties exist independently of whether or not they are quantified in PRAs Recalling Observation 1, use of PRA insights must include a qualitative description of unquantified uncertainties, in addition to those that have been quantified Any PRA-based argument for easing the regulatory requirements of the traditional approach is weakened when the unquantified uncertainties are very large and pertinent to the application Therefore, we offer the following observation

Observation 4.

Regulatory decisions must be made in the light of all the relevant uncertainties These include the uncertainties quantified in PRAs, as well as significant unquantified uncertainties Although "point" values, defined as in Observation 3, can be useful for screening purposes, they are summary measures of the probability distributions and should not be the sole basis for decisionmaking

The deliberation on uncertainties that we are recommending is best accomplished by considering the scenarios that dominate the event of interest The set of dominant scenarios is one of the most important results of PRA and has been proven to be very useful in risk management (Reference 15) A discussion of the overall uncertainties without a discussion of the sources of uncertainties is of limited value Thus, we offer the following observation

Observation 5.

The dominant scenarios should be an integral part of the deliberation on uncertainties

The regulatory decisions of immediate interest are those related to requests for changes in the current licensing basis (CLB) In discussing uncertainties, it is important to consider possible benefits of the proposed change For example, a change that reduces the regulatory burden in certain areas could allow the reallocation of resources to more risk significant issues and activities Therefore, we offer the following observation

Observation 6.

The unquantified uncertainties associated with a proposed change in the CLB should include the possible beneficial impact of the proposed change on plant safety

Finally, we note that the decisionmaking process described in Regulatory Guide 1 174 treats uncertainties and point values in a manner consistent with our recommendations as discussed in our report dated December 11, 1997 (Reference 16)

Sincerely,

R L Seale
Chairman

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