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PSA IN AMERICA

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I. Probabilistic Safety Assessment (PSA) Use in U.S. Nuclear Power

A. Historical Perspectives

Although the concept of acceptable risk has always been the foundation of the nuclear industry design, the use of formal PSA (or PRA—probabilistic risk assessment[a]) in the U.S. nuclear power industry has followed an unusual path in arriving at its current level of notability. Prior to 1975, probabilistic evaluations were limited to a few specific applications such as the evaluation of man-made (i.e., airplane crashes) and natural (i.e., earthquakes) hazards. In 1975, the industry was introduced to comprehensive PSA by the Reactor Safety Study (WASH-1400)[1]. However, the study languished in relative obscurity until the accident at Three Mile Island 2 (TMI-2) in 1979. This event significantly altered the industry's view of severe accidents in the U.S. and worldwide. Investigative committees of TMI-2 recommended that PSA techniques be more widely used to augment the traditional deterministic methods of determining nuclear plant safety. This initiated an unprecedented effort by nuclear regulators and licensees worldwide to significantly improve the state of knowledge of severe accidents at nuclear power plants. In the U.S., use of PSA began to increase as evidenced by its application in the anticipated transient without scram and station blackout rulemakings, generic issue prioritization and resolution, risk-based inspection guidelines, backfit policy, and technical specification improvements. However, broad application of probabilistic techniques to the industry as a whole was initiated in 1986 with the publication of Safety Goals for the Operation of Nuclear Power Plant; Policy Statement.[2] This put PSA front and center in the U.S. regulatory arena by "establish[ing] goals that broadly define an acceptable level of radiological risk that might be imposed on the public as a result of nuclear power plant operation." Both qualitative safety goals and quantitative objectives were articulated in this policy statement.

The next significant milestone was the issuance of NRC Generic Letter No. 88-20, Individual Plant Examination for Severe Accident Vulnerabilities.[3] This action acknowledged that, while existing plants presented no undue risk to the public, the systematic methods of PSA, when applied to individual plants, would be beneficial in the identification of plant-specific vulnerabilities to severe accidents. Examination

[a] For the purposes of this paper, the terms PSA and PRA are synonymous.

for plant-specific vulnerabilities to both internally initiated events (Individual Plant Examinations or IPEs) and externally initiated events (Individual Plant Examination of External Events or IPEEEs) were required.

To be balanced in this historical summary, not all activities have been driven by the NRC. In the 1970s and 1980s, several utilities made the financial commitment to PSA and embarked on the development of detailed analyses for their facilities. Oyster Creek (1979), Seabrook (1983), Midland (1984), TMI-1 (1987), Diablo Canyon (1988), and South Texas Project (1989) are but a few of the early industry PSA efforts. The Oconee PRA[4] (1984) was a joint effort of several utilities which combined their resources to produce a risk assessment. The Zion (1981) and the Indian Point 2/3 (1982) PRAs were used to respond to a petition to close down the plants. The petition claimed that operation of these plants in high population areas (Chicago and New York City, respectively) represented too high a risk to those populations. The PRAs were keys to the successful in rebuff of the petition.

In early 1991, the Nuclear Regulatory Commission published NUREG-1150[5], which provided an evaluation of severe accidents for five U.S. power plants using the latest methods of probabilistic analysis and supported by an extensive NRC research program in severe accident phenomenology. As a result of this work, along with companion studies and research by the nuclear power industry, advances in the understanding of in-vessel, ex-vessel, and containment behavior under severe accident conditions were realized as well as improvements in the estimation of public impacts from such accidents.

The most recent event in the movement toward PSA use in regulating nuclear power is the August 16, 1995, issuance of Use of Probabilistic Risk Assessment Methods in Nuclear Regulatory Activities; Final Policy Statement.[6] This statement articulated the policy the NRC proposes to follow in the use of PSA in all nuclear regulatory matters in which the NRC is involved, including those associated with the use, transportation, and storage of nuclear materials.

B. Direction of PSA in Nuclear Power Regulation

The policies defined by the NRC in their final policy statement were prepared with the recognition that the industry has not yet derived full benefit from PSA methods and in those limited areas which have had success, the methods have not been used consistently. Also, limitations of the technology, such as quantification of human error and safety culture, must be taken into account as this new regulatory process is molded. These observations were incorporated into the NRC's final policy statement and read as follows:

> *1. The use of PRA technology should be increased in all regulatory matters to the extent supported by the state-of-the-art in PRA methods and data and in a manner that complements the NRC's deterministic approach and supports the NRC's traditional defense-in-depth philosophy.*
>
> *2. PRA and associated analyses (e.g., sensitivity studies, uncertainty analyses, and importance measures) should be used in regulatory matters, where practical within the bounds of the state-of-the-art, to reduce unnecessary conservatism associated with current regulatory requirements,*

regulatory guides, license commitments, and staff practices. Where appropriate, PRA should be used to support the proposal for additional regulatory requirements in accordance with 10 CFR 50.109 (Backfit Rule). Appropriate procedures for including PRA in the process for changing regulatory requirements should be developed and followed. It is, of course, understood that the intent of this policy is that existing rules and regulations shall be complied with unless these rules and regulations are revised.

3. PRA evaluations in support of regulatory decisions should be as realistic as practical and appropriate supporting data should be publicly available for review.

4. The Commission's safety goals for nuclear power and subsidiary numerical objectives are to be used with appropriate consideration of uncertainty in making regulatory judgments on the need for proposing and backfitting new generic requirements on nuclear plant licensees.[6]

The key philosophy in the NRC policy is that PSA methods will be used in a manner which complements and supports the traditional deterministic and defense-in-depth approach; PSA will not replace these methods. As a companion document to the policy statement on the use of probabilistic methods in regulatory activities, the NRC also issued a PRA Implementation Plan[7] which had the goal of increasing the use of probabilistic methods in all regulatory matters. This implementation plan provided a framework to begin using PSA methods in the regulatory arena, including decision criteria for using PSA in regulation, identification and collection of essential data to support PSA use in regulation, establishing consistent methods and models for use by all regulatory offices within NRC, and training of regulators to understand and correctly implement PSA technology.

The licensees have not been idle on this issue, either. Their proposal is to have:

A regulatory approach in which operating experience and engineering judgment are used in concert with the analytical insights derived from probabilistic safety assessments to focus licensee and regulatory attention on design and operational issues commensurate with their importance to public health and safety.[8]

Such regulation would be characterized by measurable parameters to monitor performance, objective criteria to assess performance, and flexibility on how to achieve performance. It is the industry's position that, while acknowledging that the deterministic approach of the past has been very successful in assuring public health and safety, the extensive operating experience base which now exists and the PSA tools now available must be brought into the regulatory arena. This must be done in order for those aspects of a plant's operation truly important to public health and safety to be effectively and efficiently regulated.

C. Current NRC and Industry PSA Applications

The application of PSA in the regulation of nuclear power plants is increasing, but at a cautious rate. The NRC plans to publish, for public comment, regulatory guidance and standard review plans which define acceptable approaches for using PSA methods in inservice inspection, inservice testing, graded quality assurance, and technical specifications. As other regulatory areas are identified where PSA can be effectively utilized, similar documents will be prepared. Some long term consideration is also being given to the standardization of some aspects of these applications through appropriate standards organizations.

Current industry applications of PSA methods for regulatory purposes have been limited to date. Several of the licensees have performed shutdown probabilistic analyses to respond to safety concerns at operating modes other than full power. Several utilities have made some individual exploratory PSA ventures to assist in maintenance and work control and in the use of risk monitors. However, these activities have been limited to those utilities having extensive PSAs. The large majority of the licensees are investigating PSA impacts on their facilities through the various vendor owners groups and the U.S. nuclear industry policy organization, the Nuclear Energy Institute, using their IPE analyses. The drawback to this approach is the IPEs were developed to address rather narrowly defined "risk outlier" issues. Consequently, these studies do not fully conform to a comprehensive PSA analysis. Several pilot programs are presently being negotiated between the NRC and the industry to gain experience in PSA applications prior to implementing broad applications. As this experience level increases, the role of PSA methods in nuclear regulation should become more clearly defined and its usage should increase accordingly.

II. PSA Use in U.S. High and Low Level Waste Disposal

In the U.S., low-level waste does not present source terms significant enough nor processes complex enough to warrant the formal methodologies of PSA. Resolution of these issues are, consequently, relegated to more political, regulatory, and cost-benefit decision processes. On the other hand, the application of PSA principles in the areas of high-level radioactive waste (HLW) has been on the increase over the last five years. In fact, the current trend is toward the evaluation of quantitative risks for such facilities. The Nuclear Waste Policy Act of 1982 (NWPA) created the existing national program for dealing with the accumulation of spent fuel from reactors, as well as radioactive waste from reprocessing of spent nuclear fuel, and other HLW. The NWPA designated the U.S. Department of Energy (USDOE) as responsible for the permanent disposal of the nation's HLW and required that disposal be made in a geologic repository licensed by NRC. The NWPA also established a program for a monitored retrievable temporary storage facility to be developed by USDOE and licensed by NRC. However, the progress of these programs was linked to the progress of characterization and siting processes for several possible repository sites. This availability of site "choices" led to a rather protracted timeline for selection of a single site. In an effort to accelerate the process to a conclusion, subsequent legislation revised the NWPA to consider only Yucca Mountain in Nevada for site characterization. It also established a mechanism for locating a host for the retrievable storage facility, although legislation passed in 1993 has made this process more difficult. Congress is now considering legislation concerning HLW interim storage and permanent disposal that would significantly alter the national program by mandating more specifics on locations, timetables, and requirements. Proposed legislation requires an integrated DOE management system consisting of interim storage at a specified location in the state of Nevada and permanent disposal at Yucca Mountain with license applications to be submitted early in the next century. This pending legislation also includes the establishment of a public dose standard of 100 mrem/year to an individual. Past legislation deferred the establishment of such standards to other organizations, such as the Environmental Protection Agency.

III. PSA Use in U.S. Non-Reactor Nuclear Programs

For the most part, non-reactor nuclear facilities are managed by the USDOE. These encompass a wide variety of facilities including nuclear defense. Although there has been a concerted effort to incorporate probabilistic technology into the management of safety at these facilities, PSA usage in these applications is very different than usage in the nuclear power industry. This difference is primarily due to 1) the frequent inability to accurately define and characterize the hazard, 2) the profound paucity of records and data regarding both the design and operation of these facilities, and 3) limited resources. For example, there are no "design-basis accidents" which formulated the design for these facilities. Also, most non-reactor facilities in the USDOE complex are more chemical than nuclear. That is to say, these facilities do handle nuclear related materials, but they are handled using intricate chemical processes. Consequently, while both chemical and nuclear hazards are of concern, the more significant safety issues, with respect to the public, often lie with the chemical hazards rather than with the nuclear. While the rigor and structure of the nuclear power PSA process may have been found to be generally unsuitable for application at non-reactor facilities, the concept of probability and risk were noted to be most appropriate—the methods and the management use of the results were simply tailored to reflect actual conditions being evaluated.[9,10,11,12] PSA in non-reactor facility safety is generally used in a "binning" or matrix process where events are assigned to 3 to 5 broad categories of probabilities (e.g., frequent, unlikely, remote) and consequences (e.g., none, mild, severe). The categorization of individual events is supported by both engineering judgment and formal analysis. The level of management action is predicated on where the event falls in the matrix. More frequent or more severe events require a more vigorous response. Also, these facilities many times present the safety analysts with rather unusual conditions where PSA technology helps provide valuable information. An example would be taking very sparse and, sometimes, highly subjective information (e.g., interviews of retired truck drivers) to help characterize the probability of certain hazards being present in a long abandoned burial pit.

While the use of PSA in non-reactor facility safety analysis has endured a rather difficult learning curve, the applications now emerging seem to be doing a good job of balancing the difficult management issues of cost, risk reduction, and priority.

IV. PSA Use in U.S. Nuclear Research and Medicine

The NRC has oversight responsibility of licenses for the possession and use of nuclear materials in medical, academic, and industrial applications through the NRC Byproduct Materials Program. The various regulated products and uses range from large quantities of radioactive materials used in complex devices or in the manufacture of radiopharmaceuticals to small quantities used in radioactive tracer studies or found in simple devices. While risk has always been paramount in NRC's oversight activities, the 40 year operational history of this industry now provides a firm foundation for identifying opportunities for streamlining the materials program. It is in the context of this streamlining effort that PSA principles are to be applied. Both regulatory as well as risk focused options are being investigated for use in the streamlining process. As an example of risk focused options, low-risk operations could be defined and categorized such that minimal oversight and requirements would be imposed. For the high-risk applications, the existing specific regulations could be revised to be more risk-informed and performance-based.

The USDOE has oversight over some limited applications of nuclear materials for medical and research purposes. These applications lie primarily with its research reactors and accelerator programs. In these areas, the more traditional quantitative PSA methods have been employed in order to characterize the risk associated with the facilities. For example, comprehensive probabilistic safety assessments have been performed on each of the three operating research reactors within the USDOE complex. These studies have been used, with varying success, to help resolve risk sensitive issues and ease excessive regulatory burdens.

V. Conclusions

The path PSA has taken in the U.S. over the past 20 years has been rather rocky. Its increasingly broader use has been driven more by external forces (accidents, escalating costs, shrinking resources) than by the merits of the technology. Both the NRC and the nuclear industry have put forth proposed frameworks[7,8] for using PSA in regulation. While its use as a technical tool has met with relative acceptance, its use as a decision or regulatory tool has encountered general resistance and progress has been somewhat erratic. And resistance exists on the part of both the industry and the regulators. To overcome this problem, a growth in both knowledge and economic benefits must be realized. The policy makers (not just the technicians) must become more familiar with the various strengths and weaknesses of PSA. In addition, the movement to risk-based regulation must be timely enough and of sufficient breadth and stability that the industry realizes economic benefits from such a significant change. This is especially true for the nuclear power industry. Progress in these two areas will be key in whether PSA will become a major tool in defining "acceptable risk" in the U.S.

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