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PBMR Preapplication Meeting

October 27, 2006

Agenda

- Meeting Objectives
- Application Differences: PBMR vs. Exelon
- Licensing Approach Refinements Since Exelon
- Dialogue on Initial Staff Review of White Papers
- Next Steps

Meeting Objectives

- **Describe the framework of the licensing approach that leads to the successful design certification of the PBMR design**
  - Approach for establishing the regulatory framework -- to be described in the DC Application (DCA) specification
  - Approach for use of risk-informed, performance-based practices in demonstrating compliance with the regulatory framework -- described in separate papers on:
    - *PRA Approach (submitted)*
    - *LBE Selection (submitted)*
    - *SSC Classification (submitted)*
    - *Defense-in-Depth (in progress)*
- **Conduct a free exchange on the approach described in the submitted papers, assuring a reasonable understanding of each paper's intent, and fleshing out any pre-application issues**
- **Set schedule for remaining papers necessary for a fully productive pre-application process**

Application Differences

Exelon

- **COL application**
- **1x10 Module Facility**
- **Preapplication**
  - Licensing Approach
  - Design Issues
  - Operations Issues
  - Financial Issues

PBMR

- **DC application**
- **Multi-module Flexibility**
- **Preapplication**
  - Licensing Approach
  - Design Issues

Licensing Approach - Exelon

- **Elements of Exelon's proposed licensing approach was risk-informed and performance-based:**
  - Identification of applicable regulations and guidance
  - Top Level Regulatory Criteria (TLRC) for the frequencies and consequences of events
  - Probabilistic approach to selection of Licensing Basis Events (LBEs)
  - Deterministic method for SSC safety classification and development of Regulatory Design Criteria (RDC)
  - Conservative deterministic safety analysis for design basis events (Safety Related Design Conditions)
  - Special treatment of safety-related equipment to provide the necessary and sufficient reliability and capability of safety-related SSCs
- **The basic concepts of this approach were tested in the MHTGR pre-application review and supported by a detailed design description, PSID, PRA, and independent reviews as documented in NUREG-1338**

Exelon Approach for Establishing Regulatory Framework

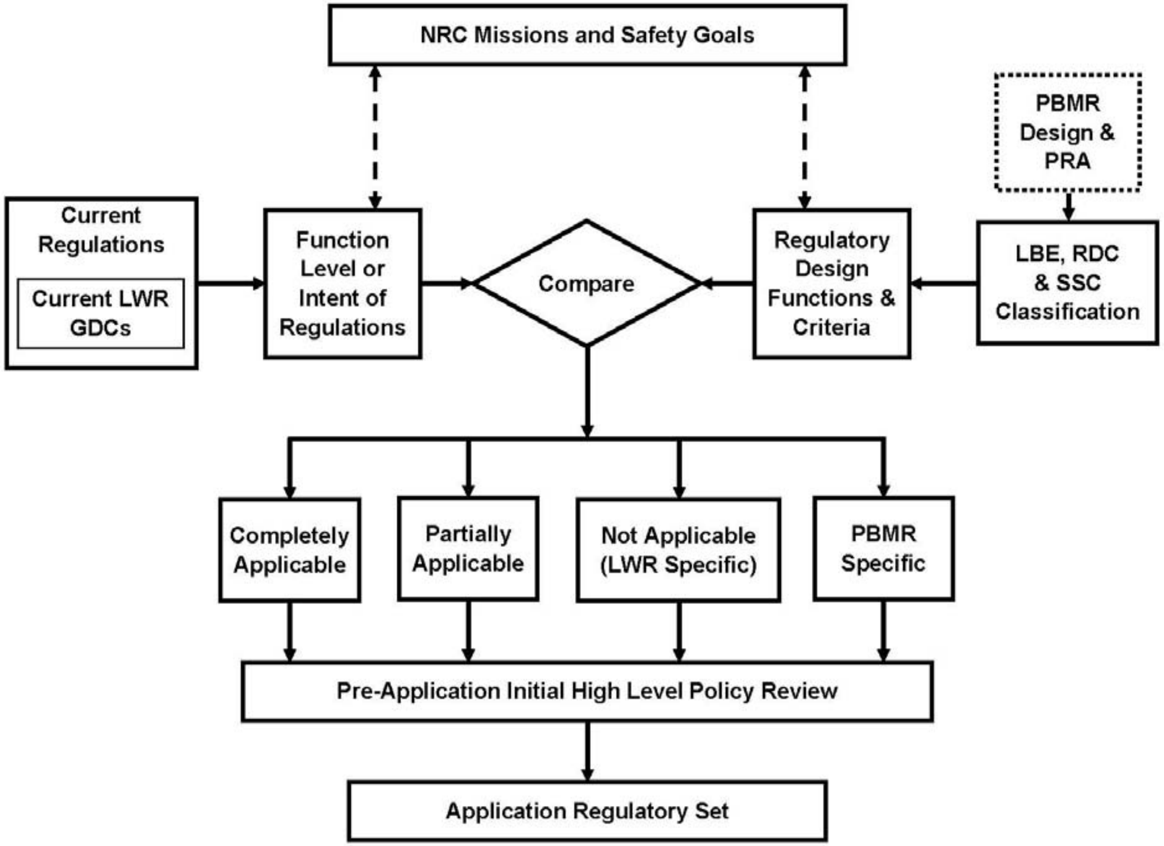

Figure 1-2 (Exelon Letter to NRC, March 15, 2002)

High Level Summary of Licensing Approach Elements per Exelon

- **What must be met?**
  - Top Level Regulatory Criteria (TLRC)
- **When must TLRC be met?**
  - Licensing Basis Events
- **How must TLRC be met?**
  - Safety Functions
  - SSC Safety Classification
  - Regulatory Design Criteria
- **How well must TLRC be met?**
  - Safety-related design conditions
  - Regulatory Special Treatment

NRC Preliminary Review of Exelon's Licensing Approach (1 of 3)

- **Screening of Regulations**
  - Agreement with approach
  - NRC intention to perform own screening in context of specific design information
- **Use of TLRC**
  - NRC acknowledged the use of TLRC as being technology-neutral, and identified several issues:
    - *Open technical issues such as frequency limits and need to consider cumulative risks and multiple modules*
    - *Observed that meeting TLRC is insufficient for establishing full licensing basis*
    - *Need to augment with defense-in-depth and deterministic (engineering judgment) criteria*

NRC Preliminary Review of Exelon's Licensing Approach *(2 of 3)*

- **Use of PRA for Selection of LBEs**
  - Staff review of events will focus on completeness
  - Question of role of "deterministically" selected events
  - SRM-93-092 cited as precedent for use of PRA
  - New risk metrics needed in lieu of CDF and LERF
  - Recognized need for event specific, mechanistic source terms
- **Treatment of Safety-Related SSCs**
  - Reiterated need to supplement TLRC with deterministic criteria
  - Need to consider safety classification for prevention as well as mitigation
  - Need to incorporate redundancy, DID, and safety margins into process
  - Recognized that NRC's risk-informed approaches are based on LWR specific metrics, e.g. CDF and LERF

NRC Preliminary Review of Exelon's Licensing Approach (3 of 3)

- **Risk-Informed Framework**
  - Consistent with NRC policy on Risk-Informed Regulation
  - Concurrence that full scope, high quality PRA is needed
  - Need for broader scope and technology neutral PRA standards
  - Expect larger uncertainties relative to LWR PRA
  - Lack of core damage state raises question about how to balance prevention and mitigation in DID philosophy
- **Policy Issues**
  - Use of PRA to select LBEs and classify safety-related SSCs
  - Need to reconcile DID philosophy for non-LWRs
  - Containment vs. confinement
  - Need for risk metrics in lieu of CDF and LERF

Developments Since Exelon

- **What has changed since Exelon that supports the PBMR approach?**
  - Policy developments, e.g. SECY-03-0047
  - NRC Technology-Neutral Framework
  - Risk-informing Part 50 initiative
  - PRA requirements, guidance and standards
  - NRC Multinational Design Assessment Program
  - Energy Policy Act and NGNP

Policy Issues (SECY-03-0047)

- **Policy issues resolved in SRM to SECY-03-0047**
  - Expectations for enhanced safety of new reactors
  - Use of PRA to select LBEs
  - Use of risk insights for SSC safety classification
  - Use of mechanistic source terms
  - Current regulations provide flexibility for emergency planning requirements
- **Issues still to be resolved**
  - Technology-neutral definition of defense-in-depth
  - Containment vs. confinement
  - Treatment of integrated risk

Path Forward for PBMR DCA

- **Build upon Exelon approach by:**
  - Addressing NRC preliminary review issues
  - Taking advantage of risk-informed policy developments
- **Establish the regulatory framework against which plant safety and preparedness are to be evaluated**
- **Apply risk-informed, performance-based methods in the analysis of plant capabilities and the establishment of programs to assure compliance with regulatory framework**
- **Apply deterministic approaches where appropriate (e.g., security)**
- **Complete pre-application review of selected focus areas**
- **Document regulatory framework, plant design, safety analysis methods, results, and commitments in the DC Application**

Establishment of Regulatory Framework

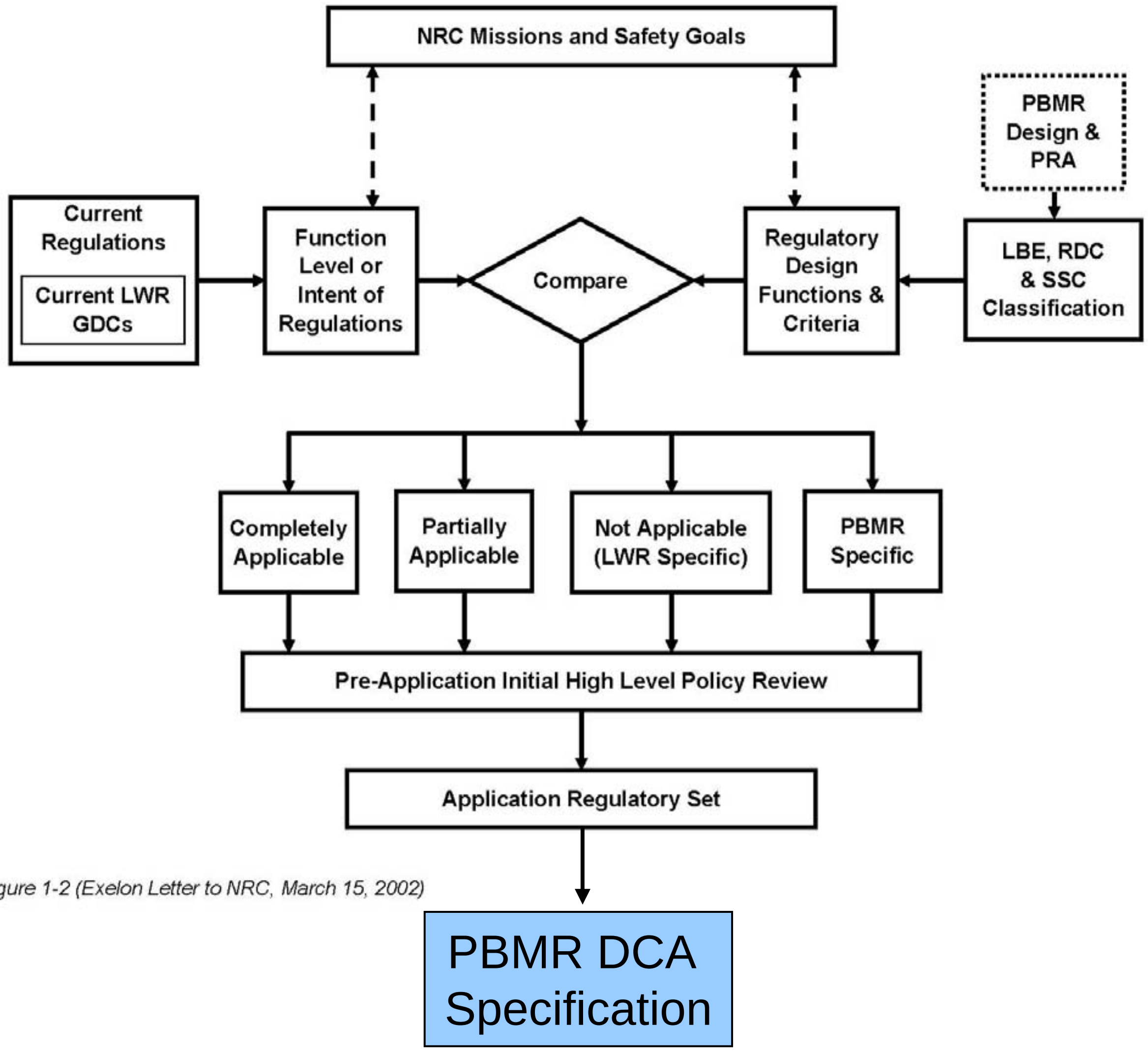

Figure 1-2 (Exelon Letter to NRC, March 15, 2002)

DC Application Structure

Submitted for Review

General Information (Corporate Identity)

Design Control Document

Introduction

Tier 1
1. Introduction
2. System Based Design Descriptions and ITAAC
3. Non-System Based Design Descriptions and ITAAC
4. Interface Requirements
5. Site Parameters

Tier 2
SAR Format
1. Introduction
2. Site Parameters
3. Design of SSCs
4. Reactor

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19. Probabilistic Risk Assessment Summary

Supporting Documents (Topical Reports)
- Probabilistic Risk Assessment
- Security Assessment
- Computer Code V&V, Scaling, Benchmark Data Reports
- Analysis of SAMDAs

Not Submitted, Available for Audit

Detailed Design and Analyses Information
- Codes and Standards Compliance
- Equipment Specifications
- Qualification Protocols
- Qualification Analyses and Test Data
- Subvendor Data

Fuel Design, Qualification and Manufacturing Data

Detailed Safety Analysis and Test Data

Procurement / Fabrication / Construction Information
- Detailed Design Layout Drawings

Quality Assurance Records

PBMR DCA Specification

- **Need to identify specific regulatory guidance impacted by PBMR's design and licensing approach**
- **Examples of DCA sections impacted by risk-informed approach:**
  - Regulatory framework and compliance (1.9, 3.1)
  - LBE selection (15.0, 6.2)
  - SSC classification (3.2)
  - Special treatment requirements (3)
- **Examples of DCA sections impacted by PBMR design:**
  - Core / graphite structures (4)
  - Passive heat removal (6)

PBMR

Evolution in Risk-Informed Processes

- **Refinements to better explain each step of the process**
- **Enhancements to approach include:**
  - Modified TLRC in AOO region
  - Explicitly address cumulative risk
  - Safety-related design conditions now described as deterministic Design Basis Accidents (DBAs)
  - Three rather than two SSC safety categories explicitly address both prevention and mitigation
  - Clarified approach to defense-in-depth and integrated it with other elements of the licensing approach (topic of a pending white paper)

Summary of Risk-Informed Elements of PBMR's Licensing Approach

- **What must be met?**
  - Top Level Regulatory Criteria (TLRC)
  - Applicable regulations and requirements
- **When must requirements be met?**
  - During all normal operating and shutdown modes
  - During Licensing Basis Events (LBEs)
  - During deterministically analyzed design basis accidents (DBAs)
- **How must requirements be met?**
  - Risk-informed approach to selection of LBEs
  - Plant Capability Defense-in-Depth
  - Risk-informed, performance-based SSC safety classification approach
  - Regulatory Design Criteria (RDC) for safety-related SSCs
- **How well must TLRC be met**
  - Conservative mechanistic safety analyses of DBEs and deterministic DBAs
  - Programmatic Defense-in-Depth

Dialogue on White Papers

Outcome Objectives - PRA Approach

1. The scope of the PBMR PRA outlined in this paper is appropriate for the intended uses of the PRA in the design certification of the PBMR. These uses include input to the identification of any risk vulnerabilities and risk-significant systems; the selection of LBEs; safety classification of SSC; and derivation of regulatory design criteria and special treatment requirements for SSC.
2. The PRA framework outlined in this paper is a reasonable approach to capture the unique and specific elements of the PBMR safety design approach and to delineate the elements of the PBMR PRA that are common to PRAs for Light Water Reactors (LWRs).
3. The PBMR approaches to initiating event selection, event sequence development, end state definition, and risk metrics are appropriate.
4. The approach to the treatment of inherent characteristics and passive SSC outlined in this paper is reasonable and consistent with the current state-of-the-art of PRA.
5. The approach to the use of deterministic engineering analyses to provide the technical basis for predicting the plant response to initiating events and event sequences, success criteria, and mechanistic source terms yields an appropriate blend of deterministic and probabilistic approaches to support the PBMR design certification.

PBMR

Outcome Objectives - PRA Approach

6. The approach to the development of a PRA database outlined in this paper, including the use of applicable data from LWRs, use of expert opinion and treatment of uncertainty, is a reasonable approach for the PBMR PRA.
7. The process for the development of a mechanistic source term outlined in this paper is a reasonable approach for this PRA application.
8. The approach for the PRA treatment of single and multiple reactor accidents in a multi-module design is sufficient to support certification of the basic single module of the PBMR for multi-module configurations.
9. The approach to using current guides and standards for LWR PRA quality and independent peer review taking into account the differences due to the PBMR's safety design approach that is outlined in this paper is an acceptable approach to determining the adequacy of the PBMR PRA for its intended uses outlined above.
10. The DCA PRA will account for uncertainties associated with as-procured, as-built, site-specific, and as-operated information in a conservative and bounding manner to provide assurance that the LBEs derived from the DCA PRA will be appropriate for as-built and as-operated plants. A design review at the Combined Operating Licence (COL) stage will be performed to confirm the validity of the LBEs.
11. Preapplication activities to set the stage for a successful PRA review suggested in this paper and agreed upon in subsequent workshops are sufficiently well defined.

Outcome Objectives - LBE Selection

1. The structured process for selecting LBEs using input from the PRA and supported by an integrated blend of deterministic and probabilistic elements is an acceptable approach for defining the PBMR LBEs.

2. The integrated blend of deterministic and probabilistic elements described in this paper establishes an appropriate performance-based and risk-informed approach for structuring the safety analyses that will be included in the DCA.

3. LBEs cover a comprehensive spectrum of events from normal operation to rare, off-normal events. Each LBE is defined as a family of individual event sequences where each family has a common initiating event, safety function response, and end state. This includes an appropriate definition of LBEs to support the integrated risk from a multi-module plant. There are three categories of LBEs:
   - Anticipated Operational Occurrences (AOOs) which encompass planned and anticipated events. The doses from AOOs are required to meet normal operation public dose requirements. AOOs are utilized to set operating limits for normal operation modes and states.
   - Design Basis Events (DBEs) encompass unplanned, off-normal events not expected in the plant's lifetime, but which might occur in the lifetimes of a fleet of plants. The doses from DBEs are required to meet accident public dose requirements. DBEs are the basis for the design, construction, and operation of the SSCs during accidents. Separate from the design certification, DBEs are also evaluated in developing emergency planning measures.

Outcome Objectives - LBE Selection

- Beyond Design Basis Events (BDBEs) which are rare, off-normal events of lower frequency than DBEs. BDBEs are evaluated to ensure that they do not pose an unacceptable risk to the public. Separate from the design certification, BDBEs are also evaluated in developing emergency planning measures.

The LBEs in all three categories will be evaluated individually to support the tasks of assessing the performance of SSCs with respect to safety functions in response to initiating events and collectively to demonstrate that the integrated risk of a multi-module plant design meets the NRC Safety Goals.

4. Acceptable limits on the event sequence consequences and the analysis basis for the LBE categories are as follows:
   - AOOs – 10 CFR Part 20: 100 mrem Total Effective Dose Equivalent (TEDE) mechanistically modeled and realistically calculated at the Controlled Area Boundary (CAB).
   - DBEs – 10 CFR §50.34: 25 rem TEDE mechanistically modeled and conservatively calculated at the Exclusion Area Boundary (EAB).
   - BDBEs – NRC Safety Goal Quantitative Health Objectives (QHOs) mechanistically and realistically calculated at 1 mile (1.6 km) and 10 miles (16 km) from the plant.

Outcome Objectives - LBE Selection

5. The frequencies of LBEs are expressed in units of events per plant-year where a plant is defined as a collection of up to eight reactor modules having certain shared systems. The limits on the frequency ranges for the LBE categories are as follows:
    - AOOs – event sequences with mean frequencies greater than 10-2 per plant-year.
    - DBEs – event sequences with mean frequencies less than 10-2 per plant-year and greater than 10-4 per plant-year.
    - BDBEs - event sequences with mean frequencies less than 10-4 per plant-year and greater than 5 x 10-7 per plant-year.
6. The frequency below which events are not selected as LBEs is 5 x 10-7 per plant-year. The PRA examines events to 10-8 per plant-year to assure that there are none just below this *de minimus* frequency.

Outcome Objectives
- LBE Selection

7. The kinds of events, failures, and natural phenomena that are evaluated include:
   - Multiple, dependent and common cause failures to the extent that these contribute to LBE frequencies.
   - Events affecting more than one reactor module.
   - Internal events and internal and external plant hazards that occur in all operating and shutdown modes and potentially challenge the capability to satisfactorily retain any source of radioactive material.
8. The deterministic DBAs for Chapter 15 of Tier 2 of the DCD are derived from the DBEs by assuming that only SSCs classified as safety-related are available to mitigate the consequences. The public consequences of deterministic DBAs are based on mechanistic source terms and are conservatively calculated. The upper bound consequence of each deterministic DBA must meet the 10 CFR §50.34 consequence limit at the EAB.
9. Uncertainty distributions are evaluated for the mean (statistical) frequency and the mean consequence for each LBE. The mean frequency is used to determine whether the event sequence family is an AOO, DBE, or BDBE. If the upper or lower bound (95%-tile or 5%-tile of the uncertainty distribution) on the LBE frequency straddles two or more regions, then the LBE is compared against the consequence criteria for each region. The mean, lower, and upper bound consequences are explicitly compared to the consequence criteria in all applicable LBE regions. The upper bound (95%-tile) for the DBE and deterministic DBA consequences must meet the 10 CFR §50.34 dose limit at the EAB.

Outcome Objectives - SSC Classification

1. The PBMR risk-informed, performance-based approach to safety classification and special treatment that blends the strengths of probabilistic and deterministic methods is acceptable.

2. The use of three safety classification categories and the bases for SSC classification in each category are acceptable:

   Safety-Related

   - For SSCs relied on to perform required safety functions to mitigate the consequences of Design Basis Events (DBEs) to comply with the dose limits of 10 CFR §50.34.
   - For SSCs relied on to perform required safety functions to prevent the frequency of Beyond Design Basis Events (BDBEs) with consequences greater than the 10 CFR §50.34 dose limits from increasing into the DBE region.

   Non-Safety-Related with Special Treatment

   - For SSCs relied on to perform safety functions to mitigate the consequences of Anticipated Operational Occurrences (AOOs) to comply with the offsite dose limits of 10 CFR Part 20.
   - For SSCs relied on to perform safety functions to prevent the frequency of DBEs with consequences greater than the 10 CFR Part 20 offsite dose limits from increasing into the AOO region.

   Non-Safety-Related

   For all other SSCs, no special treatment.

Outcome Objectives - SSC Classification

3. The special treatment for the Safety-Related (SR) category of classification is commensurate with that needed for the SSCs to perform their capability and reliability requirements during DBEs and high consequence BDBEs to meet the 10 CFR §50.34 dose limits.

4. The special treatment for the Non-Safety-Related with Special Treatment (NSRST) category is commensurate with that needed for the SSCs to perform their capability and reliability requirements during AOOs and high consequence DBEs to meet the 10 CFR Part 20 offsite dose limits.

Next Steps

- NRC to issue RAIs on submitted papers
- PBMR to submit paper on Defense-in-Depth
- PBMR to submit DC Application Specification
- Scheduling for additional FY2007 activities