OFFICE OF NEW REACTORS

ASSESSMENT OF WHITE PAPER SUBMITTALS ON DEFENSE-IN-DEPTH, LICENSING BASIS EVENT SELECTION, AND SAFETY CLASSFICATION OF STRUCTURES, SYSTEMS AND COMPONENTS

NEXT GENERATION NUCLEAR PLANT

PROJECT 0748

1.0 INTRODUCTION

The Next Generation Nuclear Plant (NGNP) project was established by Title VI, Subtitle C of the Energy Policy Act of 2005 (EPAct). As defined by the EPAct, the NGNP will be a full-scale prototype plant that will be reliable, safe, proliferation resistant, and economical and will demonstrate the commercial potential of the design and associated technologies, with a target date for completion by September 30, 2021. Per the EPAct, the mission of the NGNP is to generate electricity and/or produce hydrogen. To meet this mission, the Department of Energy (DOE) has concluded that the NGNP should be a gas cooled, very-high-temperature reactor. In addition, it is expected that NGNP or similar reactors may provide high temperature process heat for the chemical industry, refining petroleum, or extracting oil from shale and tar deposits.

To fulfill this mission, DOE is considering a modular high temperature gas reactor (HTGR) with either a prismatic block or pebble bed core and safety features described as follows:[1]

> To achieve the safety objectives for the NGNP Project, the HTGR relies on inherent and passive safety features. Modular HTGRs use the inherent high temperature characteristics of TRISO-coated fuel particles, graphite moderator, and helium coolant, along with passive heat removal capability of a low-power-density core with a relatively large height-to-diameter ratio within an uninsulated steel reactor vessel to assure sufficient core residual heat removal under loss-of-forced cooling or loss-of-coolant-pressure conditions.
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> The primary radionuclide retention barrier in the HTGR consists of the three ceramic coating layers surrounding the fissionable kernel to form a fuel particle. As shown in Figure 4, these coating layers include the inner pyrocarbon (IPyC), silicon carbide (SiC), and outer pyrocarbon (OPyC), which together with the buffer layer constitute the TRISO coating. The coating system constitutes a miniature pressure vessel that has been engineered to provide containment of the radionuclides and gases generated by fission of the nuclear material in the kernel. Thousands of these TRISO-coated particles are bonded in a carbonaceous material into either a cylindrical fuel compact for the prismatic HTGR or a spherical fuel element for the pebble bed HTGR. These fuel particles can withstand extremely high temperature without losing their ability to retain radionuclides under all accident conditions. Fuel temperatures can remain at 1600 ºC for several

[1] INL/EXT-11-22708, "Modular HTGR Safety Basis and Approach," NGNP information paper submitted September 6, 2011, Project 0748, ADAMS accession number ML11251A169, excerpt page 8.

hundred hours without loss of particle coating integrity [INL 2010a]. This high temperature radionuclide retention capability is the key element in the design and licensing of HTGRs.

As stipulated by the EPAct, the Project and the Nuclear Regulatory Commission (NRC) have been engaged in pre-licensing interactions on technical and policy issues that could affect design and licensing of the NGNP prototype. Such early interactions are encouraged by the Commission Policy Statement on the Regulation of the Advanced Nuclear Power Plants[2], which states in part:

> During the initial phase of advanced reactor development, the Commission particularly encourages design innovations that enhance safety, reliability, and security (such as those described previously) and that generally depend on technology that is either proven or can be demonstrated by a straightforward technology development program. In the absence of a significant history of operating experience on an advanced concept reactor, plans for the innovative use of proven technology and/or new technology development programs should be presented to the NRC for review as early as possible, so that the NRC can assess how the proposed program might influence regulatory requirements.

In accordance with the provisions of the EPAct, DOE and NRC prepared a report describing the NGNP licensing strategy. This report (referred to hereafter as the Licensing Strategy Report or Licensing Strategy) was submitted to Congress in August 2008 (ADAMS accession number ML082290017), and described four options for adapting existing NRC regulatory requirements, ranging from a deterministic approach similar to that used for current reactors, to a new set of risk-informed and performance-based regulatory requirements. DOE and NRC endorsed an approach designated as Option 2, which is described as follows:

> Option 2: Risk-Informed and Performance-Based Approach. This option uses deterministic engineering judgment and analysis, complemented by NGNP design specific probabilistic risk assessment (PRA) information, to establish the licensing basis (including selecting licensing basis events) and licensing technical requirements. The use of the PRA would be commensurate with the quality and completeness of the PRA presented with the application.

The Licensing Strategy Report described this approach as the "preferred option" to complete licensing within the timeframe identified by the EPAct. Option 2 was judged to be the most viable option and was expected to limit regulatory and licensing uncertainty. The other options were judged to be less viable than Option 2, and would increase this uncertainty.

DOE's contractor, Idaho National Laboratory (INL), has prepared a series of white papers addressing aspects of HTGR design in order to obtain NRC feedback on design, safety, technical, and/or licensing process issues which may affect NGNP deployment. Three of these white papers describe the approach the project intends to use to implement the Option 2 risk-informed and performance-based approach. These papers are:

> INL/EXT-10-19521, "Next Generation Nuclear Plant Licensing Basis Event [LBE] Selection White Paper," submitted on September 16, 2010 (ADAMS accession number ML102630246, referred to hereafter as the LBE white paper);

[2] "Policy Statement on the Regulation of Advanced Reactors," 73 FR 60612, October 14, 2008

INL/EXT-09-17139, “Next Generation Nuclear Plant Defense-in-Depth Approach,” submitted on December 6, 2009 (ADAMS accession number ML093480191, referred to hereafter as the DID white paper); and

INL/EXT-10-19509, “Next Generation Nuclear Plant Structures, Systems, and Components [SSC] Safety Classification White Paper,” submitted on September 21, 2010 (ADAMS accession number ML102660144, referred to hereafter as the SSC white paper).

These papers describe a series of outcome objectives which describe specific areas where the NGNP project is seeking NRC feedback and agreement on the proposed approach to be applied by the eventual NGNP license applicant. Outcome objectives for the licensing basis event selection, defense-in-depth, and SSC classification and treatment white papers are given in Appendices A, B, and C, respectively.

The assessment below was completed by NRC personnel from the Office of New Reactors and the Office of Nuclear Regulatory Research. These personnel have extensive background in HTGR technology, risk assessment, and/or regulatory processes, and are referred to hereafter as the working group. This assessment addresses each of the papers’ outcome objectives, along with any other issues associated with these topics that the working group believes may be relevant to licensing the NGNP. These topics of the three white papers are closely inter-related, and they are integral parts of the proposed risk-informed, performance-based approach. Therefore, this assessment addresses all three topics together.

This assessment does not provide a final regulatory conclusion on any aspect of the NGNP licensing approach or design. Completion of the NGNP design in accordance with the principles proposed by the white papers will not be sufficient justification for design approval or certification of a standard design. Conclusions regarding design approval or design certification will be provided in a safety evaluation of a future combined license, design approval or design certification submittal, upon the NRC Staff’s determination that the proposed design meets all current NRC regulations, consistent with NRC guidance for review of such applications, including relevant Commission policy.

Similarly, the working group’s feedback on these papers is preliminary, since many issues identified by the working group cannot be addressed or resolved until more information about the NGNP design is available. Even so, the working group believes identifying these issues is valuable for prospective designers, so that they can incorporate relevant insights into their design efforts.

The DID white paper submittal was received several months before the closely-related LBE and SSC submittals. Based on its initial examination of the DID paper, the working group issued a limited set of requests for additional information (RAIs) on July 26, 2010 (ADAMS accession number ML102020580). INL responded to this letter on September 30, 2010 (ADAMS accession number ML102770386). A more extensive set of RAIs addressing all three white papers was issued by the working group on August 3, 2011 (ADAMS accession number ML112140336). The response to this second set of RAIs was received on October 14, 2011 (ADAMS accession number ML11290A188).

2.0 ASSESSMENT

The discussion below provides the working group assessment of each outcome objective identified by the three white papers. In addition, feedback is provided regarding implementation of the NGNP Licensing Strategy, along with feedback on other issues which the working group believes may be useful as the future NGNP reactor design is developed. Certain issues discussed below are stated to be Commission policy issues. In this context, a Commission policy issue is an issue for which the working group presently believes the Commission would have to make a specific policy determination. Issues not so identified are presently deemed by the working group as amenable to determination by the NRC staff without specific policy direction from the Commission.

2.1 Licensing Basis Event Selection

The LBE white paper proposes to use a combination of deterministic and probabilistic methods to establish the NGNP licensing basis events. In general terms, Section 3.1 of the LBE white paper describes the proposed approach as follows:

1. A deterministic approach is used to select an initial event set providing a starting point for a given phase of the design process. For example, a set of initial events developed from conceptual design provides the starting point for preliminary design.

2. The LBEs are updated as the design and analysis progress. The PRA is developed and revised as the design matures. This begins to risk inform the LBE event sequences with insights gained from the PRAs conducted during the design phase as the design continues to develop.

3. A review of the LBEs is performed at the end of the design phase to evaluate conservatisms in the selected events.

The paper outlines a process where as design information scope and detail increases, probabilistic risk assessment models are improved. Those models are used in an iterative fashion to identify potential LBEs and possible measures to mitigate those events.

Designers are expected to examine the results and determine whether design changes are desirable. Any changes would be reflected in an updated model and the process repeated until the designer is satisfied that adequate performance has been achieved.

2.1.1 LBE Outcome Objective 1 – Structured Process for Licensing Basis Event Selection

The first LBE outcome objective is stated as “The structured process for selecting LBEs is an acceptable approach for defining the LBEs.”

The LBE white paper defines licensing basis events “…as the events derived from the HTGR technology and plant design that are considered by the licensing process and are used to derive design specific performance requirements for SSCs [structures, systems, and components].” The paper also states that “A combination of deterministic and probabilistic analysis is used to identify these events and evaluate the event sequences. The LBE selection process will identify event sequence families based on an identified set of initiating events and will establish the frequency of each of these event sequences.” This process is intended to be risk-informed, and performance-based.

WORKING GROUP ASSESSMENT

In addition to deterministic selection of kinds of initiating events, the LBE white paper proposes to use PRA to establish the envelope of event sequences that must be considered for licensing the NGNP. This is a new application of a plant-specific PRA in that the licensing basis events will come from PRA event sequences. For current operating reactors and new reactors deterministic judgment has been used to establish most events in the licensing basis, rather than event sequences selected from the plant PRA. As such, it can be expected that requirements and guidance for the technical adequacy of a PRA for this expanded application will need to be established and implemented. Requirements for this application will necessarily be different and likely more demanding than those for a "design PRA" that supports certification in accordance with 10 CFR Part 52. Design PRAs are expected to have incomplete models, incorporating many assumptions about plant design and operation, and will lack good data in many areas. This yields a significant uncertainty in the PRA. Uncertainties will need to be more explicitly addressed in the proposed expanded application of a PRA for reactor licensing.

The NGNP Licensing Strategy Report states that the technical approach to establishing the NGNP licensing basis and requirements is expected to involve the "selection of licensing basis events using deterministic engineering judgment complemented by insights from the NGNP PRA." The Licensing Strategy Report further states that "once the NGNP technology is demonstrated through successful operation and testing of the NGNP prototype, and a quality PRA including data becomes available, greater emphasis on design-specific PRA to establish the licensing basis and requirements will be a more viable option for licensing a commercial version of the NGNP reactor."

The Licensing Strategy approach for use of the plant PRA follows the SRM for SECY-93-092, "Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and PIUS) and CANDU 3 Designs and their Relationship to Current Regulatory Requirements," issued April 8, 1993 (ADAMS accession number ML040210725), regarding accident selection and evaluation. The Commission approved the staff recommendation that events and sequences be selected deterministically and use conservative assumptions, and be supplemented with insights from the PRA for the specific design.

An important aspect of the working group's assessment of the proposed NGNP LBE selection process focused on evaluating whether the proposed approach for applying deterministic engineering judgment to complement the insights from the NGNP PRA to select NGNP licensing basis events was consistent with the approach for applying conservative engineering judgment.

The LBE white paper states that "A combination of deterministic and probabilistic analysis is used to identify initiating events and evaluate the event sequences. The LBE selection process will identify event sequence families based on an identified set of initiating events and will establish the frequency of each of these event sequences." This process is intended to be risk-informed, and performance-based. On September 20, 2011, INL submitted INL/EXT-11-21270, "Next Generation Nuclear Plant Probabilistic Risk Assessment White Paper," (ADAMS accession number ML11265A082, referred to hereafter as the PRA white paper), which states that within the context of the NGNP white papers a deterministic process is defined as an approach that evaluates predetermined fixed scenarios based on physical principles. A deterministic process is prescriptive (in that elements of it may be imposed) and may incorporate bounding assumptions, criteria or regulations which are imposed to compensate for related uncertainties. The PRA white paper states that a probabilistic element is associated with an evaluation that explicitly accounts for the likelihood and consequences of possible accident sequences in an integrated fashion.

The working group agrees that it is appropriate to identify initiating events deterministically. In this regard, INL stated in response to RAI LBE-3 that engineering judgment determined that the design basis accidents would include pressurized and depressurized loss of forced cooling events (conduction cooldowns). Deterministic judgment would also be used in LBE selection to incorporate lessons learned in HTGR design and operations and on consideration of additional event challenges that have been postulated during previous HTGR licensing efforts. However, it is not possible to assess the adequacy of implementation of the approach until considerably more detail is provided regarding the proposed NGNP design, processes used to conduct the deterministic evaluation, and the outcome of the design effort by the reactor vendor.

Section 3.6.1of the PRA white paper also describes how a deterministic approach will be used to identify potential initiating events. It is described as a structured, step-by-step process similar to that used for LWR PRAs to define SSCs failure modes and to identify initiating events, including challenges posed by internal and external hazards. The deterministically selected initiating events begin the process of event sequence modeling in the NGNP PRA. However, it is not possible to assess the adequacy of implementation of the approach until considerably more detail is provided regarding the proposed NGNP design, processes used to conduct the deterministic selection of initiating events and the outcome of the assessment by the reactor vendor.

The PRA white paper states that deterministic judgment would also be used to address uncertainties in the PRA event sequence frequencies (e,g,, uncertainties in the reliability of SSCs in the event sequence) in categorizing events as anticipated operational occurrences (AOOs), design basis events (DBE), or beyond design basis events (BDBE), and uncertainties in the performance of SSCs (i.e., uncertainties in the capability of the SSCs) in assessing predicted consequences against the regulatory dose acceptance criteria. Finally, deterministic judgment is also used to define the design basis accident (DBA) sequences from the DBE sequences in choosing the SSCs from the list of SSCs that are capable of performing a required safety function.

The LBE white paper describes an approach that places significant emphasis on the NGNP design-specific PRA and some use of deterministic judgment for selecting the NGNP licensing basis events. The LBE white paper does not clearly describe how deterministic engineering judgment would be used to select LBEs other than to: (1) identify the kinds of initiating events and the equipment failures to be included in the PRA, (2) bound the uncertainty in the LBE sequence frequencies for purposes of categorizing events (3) bounding the uncertainty in LBE predicted dose consequence and (4) to select safety-related equipment for defining the DBAs from the DBEs.

For the first-of-a-kind NGNP, the LBE white paper does not clearly describe how engineering judgment will be used to deterministically select LBEs in the event categories that are conservative with respected to the calculated dose consequences relative to the LBEs developed from the NGNP PRA. For example, such LBE sequences would involve conservative assumptions potentially involving a combination of such aspects as conservative initiating events (i.e., initiating event severity) with respect to the resulting mechanistic source term, conservative SSC performance characteristics associated with fission product barriers and accident heat removal and conservative core thermal-fluid characteristics resulting in conservative fission product releases and FP distributions during normal operation (e.g., conservative bypass flow, during normal operation). The use of deterministic engineering judgment in these ways is intended to address, in part, the unknown unknowns associated with the safety performance of the NGNP (i.e., completeness of the NGNP PRA), and to address the intent of the risk-informed approach selected for the NGNP licensing including the selection of design basis accidents.

As stated above, the LBE white paper defines a deterministic event selection process that may impose prescriptive elements and may incorporate bounding assumptions, criteria, or imposed aspects to compensate for uncertainties. This working group believes that this is an important aspect of event selection that is not addressed in the LBE white paper.

It is the working group's view that deterministic engineering judgment should be used to select additional events that credibly bound the source terms for the event families identified using the proposed approach described in the LBE selection white paper. The additional deterministically selected events would conservatively and credibly envelop the transport and eventual release of fission products across the NGNP containment barrier system (i.e., fuel system, helium pressure boundary, reactor building) for each of the event families. Selecting additional event sequences that involve a loss of helium pressure boundary integrity is of particular importance, because they result in a pathway for fission products to be transported from the helium pressure boundary into the reactor building, and potentially, to the environment. Such events also provide the potential for enhancing the release of fission product release from the core due to chemical attack arising from the effects of air or moisture ingress, along with increased transport of fission products from the core and helium pressure boundary due natural circulation. Other examples of deterministically selected events to conservatively calculate the design basis accident source term include bounding degraded performance of a passive safety system, such as the fuel barrier or decay heat removal system.
The NGNP license applicant and NRC will need to agree upon the deterministically selected LBEs in the event categories consistent with the NGNP design and safety characteristics of the design. The working group recognizes that it will be important that any additional measures that might be considered or needed to mitigate such deterministically selected events do not inadvertently result in increased plant risk. The application of deterministic judgment in the selection of LBEs should account for data and modeling uncertainties associated with the proposed approach, and also to address unknown unknowns, or lack of adequate or directly applicable data.

The working group did not conduct an extensive review of the PRA white paper, but did examine that paper to gain insight regarding how PRA is expected to be applied to the topics addressed in this assessment. The PRA white paper summarizes how external events (e.g., fires, earthquakes, floods, high winds, transportation accidents, nearby industrial facility events) would be included in the PRA as the causes of initiating events. The response to RAI LBE-4 states that the PRA white paper describes how a draft American Society of Mechanical Engineers (ASME) standard, "Technology Neutral Probabilistic Risk Assessment Standard for Advanced Non-LWR Nuclear Power Plants", as well as supporting LWR standards, draft standards and regulatory guides that were used to develop the advanced non-LWR PRA standard, are planned to be applied to the NGNP design. The NGNP Project states that the event sequences resulting from external hazards will be selected as DBEs, BDBEs, and the deterministically selected DBAs. Seismic events will be analyzed in the context of a seismic PRA.

The PRA white paper states that because of the reduced reliance on active SSCs to perform safety functions, it is expected that safety function failures will be dominated by events and conditions that exceed the design basis envelope for passive SSCs. Extreme external hazards represent one way this can occur. The NGNP Project states that the justification for screening out any external hazards will be made in accordance with the requirements contained within the PRA standards.

The LBE white paper states, in part, that BDBEs ensure that adequate emergency planning is in place to address these highly improbable events. BDBEs are selected from those families of events whose mean frequency falls within the BDBE region, which is identified as the emergency planning basis event region.

Currently, emergency response planning is based on a spectrum of accident consequences (e.g., magnitude, timing and chemical form of releases) along with consideration of the probability of such events. This approach to selecting emergency planning basis events, (rather than other approaches such as using risk significance, event probability or cost/benefit) has been used because the consequences of a spectrum of events is viewed as providing the best means for identify adequate planning standards and establishing conservative bounds for emergency planning.

In the event that a COL or design certification application is submitted to the NRC for the NGNP, the staff will need to assess whether emergency planning basis event (EPBEs) identified on the basis of event sequence probability would provide an adequate spectrum of events for emergency response planning for NGNP. In this regard, additional deterministically selected initiating events and sequences in the BDBE region may be required to provide an adequate spectrum of accident dose consequences. Additionally, lessons learned from the effects of earthquake and tsunami at Fukushima Dai-Ichi may result in additional regulatory requirements related to selection of beyond design basis external events for advanced reactor licensing, including the NGNP. It is expected that a Commission policy decision will be needed to allow increased emphasis on the use of the plant PRA and event sequence probabilities (including screening out selected external hazards) as the basis for establishing emergency planning requirements.

SUMMARY OF FINDINGS

While the working group concludes that the proposed approach is reasonable in concept, it is not able to fully endorse the reasonableness of the approach due to the following issues:

- Deterministic elements of the proposed approach need to be strengthened to ensure conservative selection of bounding events, including events used to justify proposed emergency response measures.

- There is insufficient design detail available to fully interpret or understand how events will be selected, such as how engineering judgment regarding initiating event severity will be applied, conservative SSC performance determined, how bounding reactor thermal-hydraulic characteristics will be calculated, and how uncertainties will be identified and addressed.

2.1.2 LBE Outcome Objective 2 – Comprehensive Spectrum of Events

The second LBE outcome objective is stated as "LBEs cover a comprehensive spectrum of events from normal operation to rare, off-normal events."

The LBE white paper describes three proposed categories for LBEs which it defines as follows:

a. 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.

b. 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.

c. 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.

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.

WORKING GROUP ASSESSMENT

The NGNP Licensing Strategy report states that the technical approach to establishing the NGNP licensing basis and requirements is expected to involve establishment of licensing-basis event categories (i.e., anticipated operational occurrences, design-basis accidents, and beyond-design-basis accidents) based on the expected probability of event occurrence; within each category selection of licensing basis events using deterministic engineering judgment complemented by insights from the NGNP PRA.

The categorization LBEs into AOOs, DBEs, and BDBEs appears to be a reasonable approach for the classification of LBEs. These LBEs would include the LBEs selected using the proposed event selection process as well as the additional deterministically selected LBEs for inclusion in each category. The proposed event categories appear to be consistent with LWR event categorization practices.

NRC's regulations in 10 CFR 100 and 10 CFR 52.79[3] are applicable to NGNP design and licensing. These regulations set a dose limit of 25 rem Total Effective Dose Equivalent (TEDE) at the Exclusion Area Boundary (EAB) for the facility siting analysis. As stated in 10 CFR 52.79, in performing the siting analysis, the applicant "shall assume a fission product release from the core into the containment assuming that the facility is operated at the ultimate power level contemplated." 10 C.F.R. 52.79(a)(1)(vii). This analysis should assume a fission product release that should be based upon

[3] The NGNP white papers generally refer to requirements of 10 CFR 50.34. For the proposed combined license application, 10 CFR 52.79 is the relevant regulation, so this assessment refers to 10 CFR 52.79. However, the dose requirements discussed here are identical in the two regulations, so this is an administrative detail which has no effect on the technical requirements.

> "…a major accident, hypothesized for purposes of site analysis or postulated from considerations of possible accidental events. These accidents have generally been assumed to result in substantial meltdown of the core with subsequent release into the containment of appreciable quantities of fission products."

10 C.F.R. 52.79(a)(1)(vii) n.5. The safety basis for 10 CFR 52.79 and Part 100 is, in part, to establish defense-in-depth in the accident mitigation capability of the LWR containment system. Among other things, the requirement is intended to provide reasonable assurance that the containment system is capable of meeting the Part 100 dose guidelines even for a "major accident" or "postulated event" which results in the release into the containment of appreciable quantities of fission products.

In SECY-93-092, "Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and Process Inherent Ultimately Safe [PIUS]) and CANDU 3 Designs and Their Relationship to Current Regulatory Requirements," April 8, 1993, the staff described the approaches proposed by non-light- water reactor (LWR) designers for the selection of events to be considered in the design and for safety classification. The approach proposed in SECY-93-092 included the following aspect: "A set of events would be selected deterministically to identify a containment challenge scenario." In response to SECY-93-092 the Commission issued a staff requirements memorandum (SRM) on July 30, 1993, which approved the staff proposals.

The principle that the containment system must provide defense-in-depth to prevent unacceptable fission product releases for the unknown or unexpected events is presented in a technology neutral manner in NUREG-1860, Volume 1, "Feasibility Study for a Risk-Informed and Performance-Based Regulatory Structure for Future Plant Licensing." Section 4.3, Defense-in-Depth Objectives and Principles of NUREG-1860, includes Principle 5, "The plant design has containment functional capability to prevent an unacceptable release of radioactive material to the public."

As stated in NUREG-1860, the purpose of this principle is to "protect against unknown phenomena and threats, i.e., to compensate for completeness uncertainty affecting the magnitude of the source term." Principle 5 further states: "The design of the controlled leakage barrier should be based upon a process that defines a hypothetical event representing a serious challenge to fission product retention in the fuel and the coolant system. The applicant and NRC should agree upon a hypothetical event, consistent with the technology and safety characteristics of the design. The principle recognizes that the particular means used to retain or control the release will depend on the reactor technology"

Principle 5 describes the containment system as an essential aspect of the NRC's defense-in-depth philosophy and provides a design basis approach and criteria for the defense-in-depth capability of the containment system. The containment system must be shown to be capable of preventing an unacceptable release of radioactive material to the public for a hypothetical event representing a serious challenge to fission product retention in the fuel and the coolant system. The NGNP Mechanistic Source Term (MST) White Paper (submitted on July 21, 2010, ADAMS accession number ML102040260) describes the NGNP functional containment system as comprising several barriers that limit the release of radionuclides to the environment (defined as the source term) for each postulated event, including normal operating conditions, abnormal operating conditions, and accident conditions. Neither the NGNP LBE White Paper nor the

NGNP MST white paper identified an approach or criteria for demonstrating the defense-in-depth capability of the functional containment system.

It is the working group's view that, for the NGNP the dose guidelines in 10 CFR Part 100 should be met for a hypothetical event representing a serious challenge to fission product retention functional containment system in the fuel and the coolant system. It is also the working group's view that events in the frequency range 1E-5 per reactor-year to 1E-7 per reactor-year should be considered in identifying hypothetical events that represent a serious challenge to fission product retention of the NGNP functional containment system. That is, events in the BDBE frequency range should also be considered to ensure that the NGNP functional containment system provides sufficient defense-in-depth for meeting 10 CFR Part 100 dose limits for a "major accident" or "postulated event" which results in the release of appreciable quantities of fission products, as required by 10 CFR 52.79.

The working group believes that whether LBE sequences below the lower frequency cutoff for the DBE region (i.e., 1E-5 per reactor-year) can be excluded from the accidents considered in developing the NGNP siting source term and assuring adequate DID of the NGNP functional containment system presents policy issues that the Commission would have to determine. Additionally, design basis events have been identified using deterministic engineering judgment for current reactors; establishment of a frequency cutoff criterion involves interpretation of regulations (e.g., 10 CFR 50.34(a)(1)(ii)(D) or 52.17(a)(1)(ix)) in a new manner, and, as such, presents policy issues that the Commission would have to determine.

SUMMARY OF FINDINGS

The working group agrees that categorization of events as AOOs, DBEs, and BDBEs appears to be a reasonable approach. However, the working group believes that it will be necessary to consider bounding events which would otherwise fall within the BDBE region as design basis events in order to ensure adequate defense-in-depth for containment of fission products, in accordance with regulatory requirements. The working group also expects that a Commission policy decision will be required before such events are excluded from consideration as design basis events.

<u>2.1.3 LBE Outcome Objective 3 – Licensing Basis Event Frequency Ranges</u>

The LBE white paper proposes that the frequencies of LBEs be expressed in units of events per plant-year, where a plant is defined as a collection of reactor modules having certain shared systems. The proposed frequency ranges for the LBE categories are as follows:

a. AOOs – event sequences with mean frequencies greater than 1E-2 per plant-year

b. DBEs – event sequences with mean frequencies less than 1E-2 per plant-year and greater than 1E-4 per plant-year

c. BDBEs - event sequences with mean frequencies less than 1E-4 per plant-year and greater than 5E-7 per plant-year.

WORKING GROUP ASSESSMENT

To account for multi-module plants, the LBE white paper proposes that the frequency be stated on a per plant-year basis. NGNP is expected to involve a single reactor module, in which case, a reactor-year and a plant-year would be the same. However, the LBE white paper seeks to lay the ground work for defining event frequency ranges that can be applied to multi-module plants.

The NGNP Licensing Strategy report states that the technical approach to establishing the NGNP licensing basis and requirements is expected to involve the establishment of licensing-basis event categories (i.e., abnormal occurrences, design-basis accidents, and beyond-design-basis accidents) based on the expected probability of event occurrence. Within each category, selection of licensing basis events uses deterministic engineering judgment, complemented by insights from the NGNP PRA.

As stated above, the NGNP Project proposes that the frequency of LBEs be expressed on a per plant-year basis where a plant is defined as a collection of reactor modules having selected shared systems and that the guidelines for the upper and lower frequency bounds for categorizing events be on a per plant-year basis. Therefore, for events involving a single reactor module, the frequency ranges per reactor module per year would be the proposed frequency ranges divided by the number of reactor modules that comprise the plant. For example, for such events, as stated above, for an eight reactor module plant design, the proposed lower frequency cutoff of 1E-4 per plant-year for DBEs impacting only one of an eight reactor module plant would result lower frequency cut off guideline of about 1E-5 per reactor-year. However, for a 4 reactor module plant design, the proposed lower bound frequency cutoff of 1E-4 per plant-year for DBEs impacting only one of a 4 reactor module facility would result lower frequency cut off guideline of about 2.5E-5 per reactor-year. Thus, the cut-off frequencies on a reactor-year basis would vary depending on the number of reactor modules in the plant. To be consistent with the regulatory practices for the lower frequency cutoff for LWR events, it is the working group's view that the lower frequency cutoff for the NGNP on a reactor-year basis for DBEs should be comparable to the frequency range cutoff associated with a single large LWR plant (1E-5 per reactor-year), which is consistent with the approach documented in NUREG-1860. Similarly, as shown in NUREG-1860 Table 6.3, "LBE Criteria," it is the working group's view that an appropriate event frequency range for DBEs is 1E-2/year to 1E-5/year.

SECY-03-0047, "Policy Issues Related to Licensing Non-Light-Water Reactor Designs", dated March 28, 2003 (ML030160002) included Issue 4, "Probabilistic Event Selection, Safety Classification and Reliability Criteria." The discussion of Issue 4 included a table entitled "Example of Event Selection Criteria." The table provides an example of licensing basis event categories, dose acceptance for each category and frequency range for each category. The table presented AOOs as having a frequency greater than 1E-2 /plant-year; DBEs as having a frequency range of 1E-2/plant-year to 1E-6/plant-year and; emergency planning basis events (i.e., BDBEs) having a frequency range between 1E-6/plant-year and 1E-8/plant-year. A footnote in the table proposes that the frequency range for each event category apply to the initiating event frequencies or event scenario (i.e., event sequence) frequencies. The footnote is based, in part, on current LWR regulatory practices, which generally considers the initiating event frequency rather than the event sequence frequency for categorizing events.

For example, in connection with risk-informing loss of coolant accident (LOCA) requirements, in the Staff Requirements Memorandum (SRM) for SECY-04-0037, dated June 26, 2003, (ADAMS accession number ML031770333) the Commission stated that "the staff should use the initiating event frequencies to guide the determination of an appropriate alternative break size and the staff should use the approach and guidance in Regulatory Guide (RG) 1.174 to assure that the selection of the maximum break size is risk-informed and conforms to the RG 1.174 safety principles. For example, a frequency of 1 occurrence in 100,000 reactor-years [i.e., 1E-5/reactor-year] is an appropriate mean value for the LOCA frequency guideline for selecting the maximum design-basis LOCA." The alternative break size is the largest pipe break to be categorized as a DBA. Breaks larger than the alternative break size would be considered breaks in the BDBE category

Consistent with this guidance, it is the working group's view that DBEs involve event sequences or initiating events with mean frequencies less than 1E-2 per reactor-year and a mean frequency greater than 1E-5 per reactor-year. For a four reactor module multi-modular plant, this would be equivalent to event sequences or initiating events with mean frequencies less than 4E-2 per plant-year and a mean frequency greater than 4E-5 per plant-year

Additionally, it is the working group's view that BDBEs should involve event sequences or initiating events with mean frequencies less than 1E-5 per reactor-year and a mean frequency greater than 1E-7 per reactor-year. For a four reactor module multi-modular plant this would be equivalent to event sequences or initiating events with mean frequencies less than 4E-5 per plant-year and a mean frequency greater than 4E-7 per plant-year. In contrast, the LBE white paper categorizes events on sequence frequency alone.

It is the working group's view that the above frequency ranges are only guidelines and not sharp demarcations of the event category frequency boundaries. In the categorizing of events, the working group believes that conservative engineering judgment will need to be applied to address the uncertainty in the LBE frequency.

The frequency ranges as well as whether both event sequence frequency and initiating event frequency should be considered in the categorization of LBEs are considered Commission policy issues.

Finally, the working group requested clarification in RAI LBE-17 whether the events that would be used for the design basis for safety-related SSCs designed to national codes and standards, (e.g., ASME Boiler and Pressure Vessel Code, Section III) would be based on events in a specific frequency range (e.g., DBE frequency range) or be based on events and conditions defined by the code. INL responded that the selection and application of codes and standards and the associated design rules will not be solely based on event frequencies as defined for design basis events. For example, INL states that, in the case of the reactor coolant pressure boundary, the ASME Section III construction rules would be applied. The approach described in the RAI LBE-17 response is reasonable.

SUMMARY OF FINDINGS

The working group believes that the proposed frequency ranges for DBEs and BDBEs should be defined in a more conservative manner.

- An appropriate frequency range for DBEs is 1E-2/reactor-year to 1E-5/reactor-year.

- An appropriate frequency range for BDBEs is 1E-5/reactor-year to 1E-7/reactor-year.

The definition of frequency ranges for the various event categories is considered a Commission policy issue, since it involves a new interpretation of the regulations and associated guidance for demonstrating compliance.

2.1.4 LBE Outcome Objective 4 – Event Consequence Acceptance Limits

The LBE white paper proposes that acceptable limits on the event sequence consequences and the analysis basis for the LBE categories are as follows:

a. AOOs – 10 CFR Part 20: 100 mrem total effective dose equivalent (TEDE) mechanistically modeled and realistically calculated at the EAB

b. DBEs – 10 CFR 50.34: 25 rem TEDE mechanistically modeled and conservatively calculated at the EAB

c. 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.

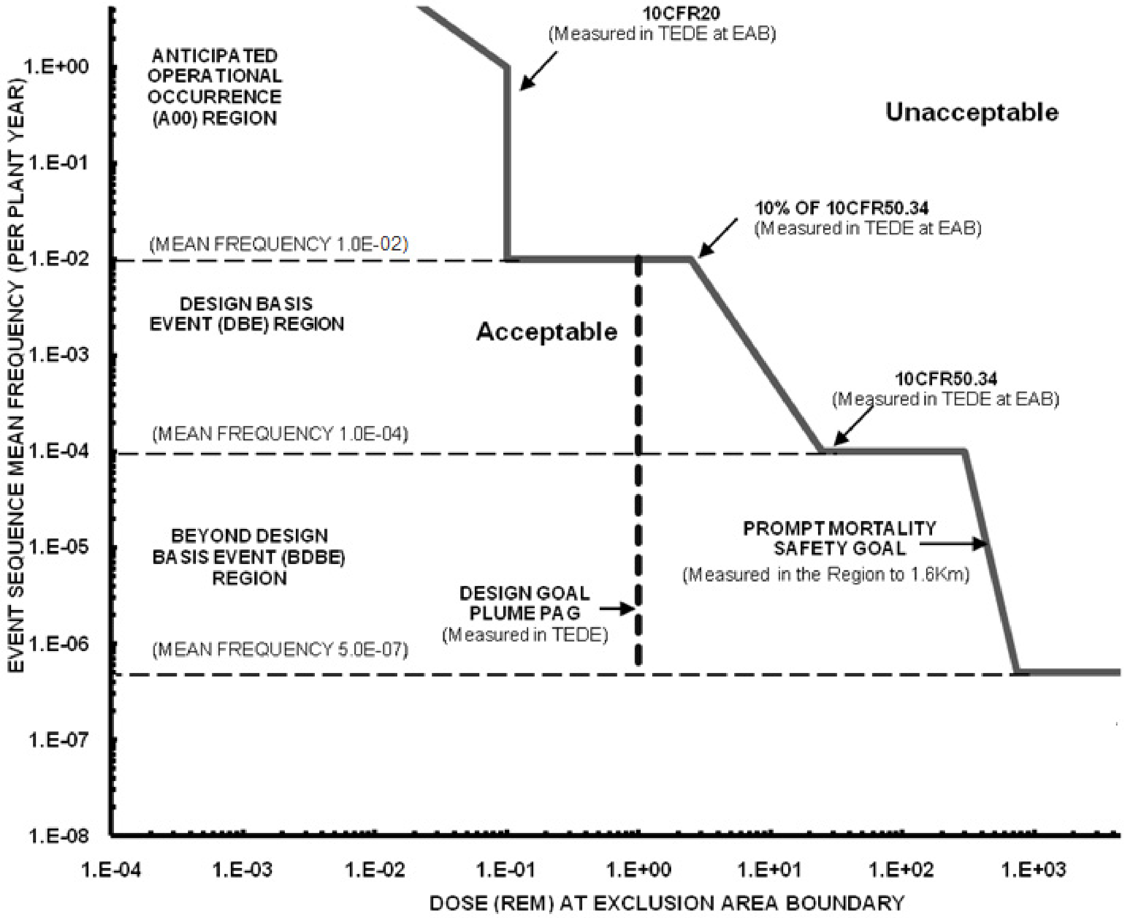
The LBE white paper states that the proposed acceptable public consequences have been derived from the existing regulations and policy, as described in Section 2 of the paper. The annual dose limits in 10 CFR Part 20 would be applicable to AOOs and the 2 hour dose limit in 10 CFR 50.34 would be applicable to DBEs and the DBAs. The safety goal QHOs would be applicable to BDBEs and would be applied to all the LBEs in an integrated manner. The analyses bases are stated to follow the conventional practice for each of the LBE categories and the respective Top Level Regulatory Criteria (TLRC).

WORKNG GROUP ASSESSMENT

The NGNP Project proposes dose acceptance limits on the LBE consequences and the analysis basis for the LBE categories which are generally consistent with the NGNP LS with several significant exceptions. The proposed dose acceptance limits for the NGNP safety analyses are depicted by Figure 3 in the NGNP LBE Selection White Paper. Figure 3 is reproduced below.

The event frequency versus dose consequence acceptance line shown in this figure is generally referred to as an “F-C curve.” For events in the AOO frequency region, the proposed F-C curve has been constructed based on the dose limits in 10 CFR Part 20. For events in the DBE frequency region, the proposed F-C curve has been constructed based on the dose limits in 10 CFR 50.34.[4] For events in the DBE region, the proposed F-C has been constructed such that a reduced dose would be allowed as DBE frequency increases. For the DBAs (which are selected and derived from the DBEs), it is proposed that dose criteria in 10 CFR 50.34 apply (i.e., without reduction). For events in the BDBE frequency region, the proposed F-C curve has been constructed based on the prompt mortality safety goal. It is proposed that the dose limits be associated with and apply at the NGNP exclusion area boundary (EAB).

[4] As noted above, the requirements of 10 CFR 50.34 are the same as those in 10 CFR 52.79, which is the regulation pertinent to a combined license, which is the planned application type for NGNP, as described in the Licensing Strategy Report.



The overall construction of the proposed F-C curve is intended to generally follow an iso-risk curve, such that low doses are allowed for relatively frequent events, while higher dose limits are allowed for rare events. The F-C curve is constructed with the intent to ensure that the overall NGNP risk for all LBEs combined will meet the NRC's Safety Goals.

The Licensing Strategy report states that technical approach to establishing the NGNP licensing basis and requirements is expected to involve the use of consequence acceptance limits for onsite or offsite releases for licensing-basis events that are consistent with current dose limits for LWRs in 10 CFR Part 20, "Standards for Protection Against Radiation," and 10 CFR 50.34, "Contents of Construction Permit and Operating License Applications; Technical Information." [5] The dose requirements of 10 CFR 50.34 and 10 CFR 52.79 are equivalent, so there is no technical distinction between these requirements for the purposes of the F-C curve discussion. The NGNP Licensing Strategy report also states that the assessment of radiological consequences for licensing-basis events would be assessed using event-specific mechanistic source terms.

[5] Again, as noted above, the Licensing Strategy also describes a plan for a combined license application, where the pertinent regulation is 10 CFR 52.79.

The working group recognizes that there are a large number of ways to construct an F-C curve that utilizes the dose acceptance criteria of existing NRC regulations and applies them to inferred frequency ranges for the event categories to meet the above stated objectives. For example, the proposed frequency consequence curve shown in Figure 3-3 of NUREG-1860 was developed in connection with the NRC staff's feasibility study for a risk-informed and performance-based regulatory structure for future plant licensing. The F-C curve shown in Figure 3-3 of NUREG-1860 was developed using the same LWR regulations used to develop the F-C curve proposed by the NGNP project. The development of the F-C curve in NUREG-1860 also includes consideration of additional dose acceptance criteria associated with national and international radiological health standards.

The working group evaluated whether the specific F-C curve proposed for the Project associated the NRC's top level regulatory requirements (i.e., dose criteria) with event frequency ranges in an appropriate and reasonable manner. The working group's evaluation also considered whether the proposed analysis rules (e.g., best estimate, conservative) were appropriate for performing the deterministic safety analysis for the events in each category. The working group's evaluation of the proposed F-C curve did not seek to establish an F-C curve that would be applied to all reactor technologies on a technology-neutral basis for future plant licensing.

Acceptance Criteria for Anticipated Operational Occurrences

It is the working group's view that, as proposed for AOOs by the LBE white paper, the regulatory limits contained in 10 CFR Part 20 should apply (i.e., 100 mrem TEDE) at the EAB. The LBE white paper proposes that the calculation of the dose at the EAB for each AOO be mechanistically modeled and realistically calculated.

In SECY-03-0047, the staff proposed that the dose consequences of AOOs be calculated on a conservative basis. More recently, as documented in Table 6-3 in NUREG-1860, the staff proposed that, with the exception of the mechanistic source term calculation, realistic calculations be conducted to obtain the mean and uncertainty distribution for estimating the consequences. That is, while the source term calculation should model all SSCs that have a role in determining AOO consequences, the staff proposed that the mechanistic source term calculation use a conservative 95% probability value.

It is the working group's view that the dose calculation model for AOOs should include all the SSCs that have a role in the deterministic safety analysis of the event sequence, but that a conservative calculation of the mechanistic source term should be used to demonstrate that 10 CFR 20 dose limits are met.

Additionally, LWR safety requirements include establishment of safety limits on the principal fission product barriers, such as the fuel barrier, and that the established safety limits not be exceeded for AOOs. Regulatory guidance provides that conservative calculation methods and assumptions be used to demonstrate that the established safety limits are not exceeded. For LWRs, assuring barrier integrity is considered an element of defense-in-depth for AOOs.

The defense-in-depth principles contained in NUREG-1860 also include the expectation that appropriate safety limits will be placed on the key barriers, such as the fuel barrier. The safety limit is established to ensure that there is very low probability of loss of the barrier safety function and that the applicant demonstrated that the appropriate limits are met with high confidence. NUREG-1860 advocates using the 95% probability value of the design distribution be used to show that the regulatory (i.e., safety) limit is met.

The NGNP White Paper on Fuel Qualification does not identify, (or identify a need for) a safety limit for the NGNP fuel barrier for AOOs or any other event category. As such, the Project has not proposed to provide separate calculations to demonstrate a required level of fuel integrity is met for AOOs. Rather the NGNP Project has proposed a concept involving multiple barriers where the combined effectiveness of all barriers must be shown to be sufficiently effective to meet the top level regulatory requirements such as 10 CFR 20.

It is the working group's view that the Project should pursue the development of an appropriate regulatory limit (e.g., a technical specification limit) to ensure the required level of integrity of the fuel barrier during normal operation as well as AOOs. As a minimum, it is the working group's view that the deterministic safety analyses for AOOs should include the demonstration that the fuel design limits (i.e., the maximum design conditions, such as the maximum fuel irradiation temperature, associated with the NGNP fuel qualification test program) are not exceeded during any AOO.

Current regulatory practice uses conservative calculations to demonstrate conformance with AOO acceptance criteria. In addition, presently, AOOs are not expected to yield offsite dose consequences. The NGNP Project proposes a best estimate calculation with some level of potential offsite consequences. The working group believes that, while use of 10 CFR 20 to establish AOO acceptance criteria is appropriate, calculations demonstrating compliance with those criteria should be done conservatively for events which, by definition, are considered likely to occur within the lifetime of the facility. However, this use of the F-C curve and whether associated calculations should be best estimate or conservative is considered to be a potential Commission policy issue, since it involves a new interpretation of the regulations and associated guidance for demonstrating compliance.

Acceptance Criteria for Design Basis Events

It is the working group's view that for DBEs (i.e., DBAs), the regulatory limits specified in 10 CFR 50.34 and 10 CFR 52.79 apply (i.e., 25 rem TEDE) at the EAB. The LBE white paper proposes that the doses be mechanistically modeled and conservatively calculated. The proposal to conservatively calculate the mechanistic source term and the dose consequences for DBEs is consistent with the earlier staff views documented in the table for Issue 4, in SECY-03-0047, and Table 6-3 in NUREG-1860, and is considered reasonable.

Acceptance Criteria for Beyond Design Basis Events

The LBE white paper proposes that for BDBEs, the NRC safety goal QHOs should apply and that these dose consequences of BDBEs be mechanistically modeled and realistically calculated at 1 mile (1.6 km) and 10 miles (16 km) from the plant.

As stated in LBE Selection Outcome Objective 2, it is the working group's view that not only should BDBEs be evaluated to ensure that they do not pose an unacceptable risk to the public, they should also be considered in developing the accident source term for purposes of the NGNP siting analysis under 10 CFR 50.34 or 10 CFR 52.79, and assuring defense-in-depth in the capability for containment of fission products.

The working group believes that it is a Commission policy issue on whether LBE sequences below the lower frequency cutoff for the DBE region (i.e., 1E-5/reactor-year) can be excluded from the accidents that are to be considered in developing the NGNP siting source term for which 10 CFR 50.34 or 10 CFR 52.79 dose criteria would apply, and assuring adequate DID for containment of fission products.

SUMMARY OF FINDINGS

The working group believes that the proposed F-C curve and associated dose calculation framework should be revised.

- Use of 10 CFR 20 to define AOO acceptance criteria is appropriate, but the associated dose calculations should be done conservatively, as opposed to realistically.

- Regulatory controls should be established to ensure fuel integrity is maintained throughout the normal operation envelope and for AOOs

- Acceptable DBE doses should be derived from regulatory limits given in 10 CFR 50.34 and 10 CFR 52.79 (i.e., 25 rem TEDE)

- The proposal to conservatively calculate the mechanistic source term and the dose consequences for DBEs is consistent with the earlier staff views, and is considered reasonable.

- NRC safety goal QHOs should apply to BDBEs, calculating doses based on realistic mechanistic models.

- Bounding events which would otherwise fall within the BDBE region should be evaluated to to ensure adequate defense-in-depth for containment of fission products, in accordance with regulatory requirements.

- Deterministic elements of the proposed approach should be strengthened to ensure conservative selection of bounding events, including events used to justify proposed emergency response measures.

Similar to the findings in section 2.1.3, the definition of dose acceptance criteria for the various event categories is considered a Commission policy issue, since it involves a new interpretation of the regulations and associated guidance for demonstrating compliance.

2.1.5 LBE Outcome Objective 5 – Lower Bound of Event Frequency

The LBE white paper proposes that the frequency below which events are not selected as LBEs is 5E-7 per plant-year. The PRA examines events to 1E-8 per plant-year to assure that there are none just below this de minimus frequency. BDBEs will be evaluated to ensure they meet the NRC safety goals at the prescribed distances from the plant. The NGNP project proposes 5E-7 per plant-year, claiming that lower frequency events meet the NRC safety goal QHO for acute individual risk of fatality.

WORKING GROUP ASSESSMENT

As discussed in LBE Selection Outcome Objectives 2 and 4, it is the working group's view that not only should BDBEs be evaluated to ensure that they do not pose an unacceptable risk to the public, they should also be considered in developing the accident source term for purposes of the NGNP siting analysis under 10 CFR 50.34 or 10 CFR 52.79 and assuring defense-in-depth for containment of fission products.

As documented in the table for Issue 4, in SECY-03-0047, and Table 6-3 in NUREG-1860, the staff provided examples of event category frequency ranges including frequency ranges for events in the lowest frequency category. In SECY-03-0047, the staff stated its preliminary view that events in the lowest frequency category (i.e. events considered for emergency planning) should consider initiating events or event sequences down to 1E-8/plant-year. In the SRM for SECY-03-0047, the Commission approved the staff recommendations for Issue 4.

NUREG-1860, Table 6-1, "Proposed dose/frequency ranges for public," extends the F-C curve dose consequence limits for events down to a frequency of 1E-7 per year. Further, NUREG-1860, Section 6.4, "LBE Selection Process and LBE Criteria" documents a proposed LBE selection process, including the lower bound frequency for events to be included in the event selection process. Step 2 of the proposed process states that all PRA sequences with point estimate frequency < 1E-8 /yr should be dropped from consideration as potential LBEs. Step 3 of the proposed states that for sequences having a point estimate frequency equal to or greater than 1E-8/yr, the mean and 95th percentile frequency should be determined. Finally, Step 4 of the proposed process states that all PRA event sequences with a 95th percentile frequency > 1E-7 per year should be identified for inclusion in the event categories.

As previously stated in the working group's assessment of LBE outcome objective 3, it is the working group's view that BDBEs should include event sequences or initiating events with mean frequencies down to 1E-7 per reactor-year. For a multi-modular plant with four reactor modules, this would be equivalent to event sequences or initiating events with mean frequencies greater than 4E-7 per plant-year. It is the working group's view that 1E-7 per reactor-year provides a reasonable cutoff for assessing whether the NGNP meets the NRC safety goals. It is also the working group's preliminary view that PRA event sequences with a point estimate below 1E-8 per plant-year can be dropped from consideration as potential LBEs.

The PRA event sequence frequency cutoff for establishing emergency planning requirements is considered a Commission policy issue.

SUMMARY OF FINDINGS

The working group believes that BDBEs should consider events with a mean frequency of 1E-7/reactor-year or more. A Commission policy decision will be required to define the event frequency used to establish emergency planning requirements.

2.1.6 LBE Outcome Objective 6 – Events, Failures, and Natural Phenomena Evaluated

The LBE white paper proposes that the kinds of events, failures, and natural phenomena that will be evaluated include:

a. Multiple, dependent, and common cause failures to the extent that these contribute to LBE frequencies

b. Events affecting more than one reactor module

c. Internal events (including transients and accidents) 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.

The PRA supporting the application will be a full scope (including all operating modes) evaluation. The PRA white paper provides additional information on this approach.

WORKING GROUP ASSESSMENT

The NGNP Licensing Strategy report states that the technical approach to establishing the NGNP licensing basis and requirements is expected to involve the "…selection of licensing basis events using deterministic engineering judgment complemented by insights from the NGNP PRA." The Licensing Strategy further states that "once the NGNP technology is demonstrated through successful operation and testing of the NGNP prototype, and a quality PRA including data becomes available, greater emphasis on design-specific PRA to establish the licensing basis and requirements will be a more viable option for licensing a commercial version of the NGNP reactor."

The PRA White Paper addresses the approach to the development of the NGNP PRA, including the kinds of events, failures, and natural phenomena that are to be evaluated. As discussed earlier in LBE Outcome Objective 1, Section 3.6.1of the PRA white paper describes how a deterministic approach will be used to identifying potential initiating events. The PRA white paper also describes the approach to the modeling of multiple, dependent, and common cause failures. The working group agrees that the NGNP PRA will need to include an evaluation of multiple, dependent, and common cause failures. The working group agrees that the evaluation of multiple, dependent, and common cause failures by the PRA will contribute to both LBE frequencies, but such kinds of failures can also contribute to the LBE consequences. Events affecting more than one reactor module will need to be considered for a plant with multiple reactor module.

The working group agrees that internal events (including transients and accidents) 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 should be included in the NGNP PRA. For the NGNP, this would include both internal events initiated by faults and failures in the BOP, including a process heat facility as well as external events initiated by the NGNP's proximity to a nearby process heat facility.

The working group agrees that the kinds of events and failures, and natural phenomena that should be evaluated should include those proposed by the NGNP Project and that a full scope PRA for all NGNP modes (i.e., operating, shutdown) and all sources of radioactive material (e.g., reactor core, spent fuel storage, waste clean-up and handling systems) should be used for the assessment.

Finally, as stated in working group's assessment of LBE Selection Outcome Objective 1, the lessons learned from Fukushima Dai-Ichi may result in additional regulatory requirements related to the analysis of external events (e.g., natural phenomena) and the associated event sequences to be considered for NGNP licensing. Such additional requirements have yet to be established.

SUMMARY OF FINDINGS

The working group agrees with the proposed scope of events and phenomena to be considered, but notes that additional requirements may arise from NRC's evaluation of lessons learned from Fukushima Dai-ichi.

2.1.7 LBE Outcome Objective 7 – Design Basis Accidents

The LBE white paper states that DBAs for Chapter 15, "Accident Analysis," of the license application are derived from the DBEs by assuming that only SSCs classified as safety-related are available to mitigate the consequences. The public consequences of DBAs are based on mechanistic source terms and are conservatively calculated. The upper bound consequence of each DBA must meet the 10 CFR 50.34 consequence limit at the EAB.

WORKING GROUP ASSESSMENT

In the working group's view as stated above, in the proposed NGNP approach, DBAs that are derived from the DBEs by demonstrating success paths for the DBAs relying solely on the response actions of safety-related SSCs follows regulatory requirements and practice. That is, DBAs are selected from LBE sequences that have a proposed event sequences frequency of between 1E-2 per plant-year and greater than 1E-4 per plant-year (see LBE Outcome Objective 3). Further, the working group agrees that the consequences of DBAs can be based on event-specific mechanistic source terms, and that these source terms should be calculated on conservative basis. However, the details of the conservative mechanistic source term calculation methodology have not yet been provided, so the working group has not been able to evaluate whether the margin associated with such calculations is reasonable. It is expected that any staff determination on this issue would be made during interactions with the NGNP license applicant.

As stated in the assessment of LBE Selection Outcome Objective 2, it is the working group's view that events in the BDBE frequency range should also be considered in developing the accident source term for purposes of the NGNP siting analysis. The working group believes that it is a Commission policy issue on whether DBAs derived from sequences below the lower frequency cutoff for the DBE region (i.e., 1E-5/reactor-year) can be excluded from the accidents considered in developing the NGNP siting source term for which dose criteria cited in 10 CFR 50.34 or 10 CFR 52.79 would apply.

For example, selected BDBEs that involve the failure of the helium pressure boundary may have the potential to result in significant and prolonged air ingress into the reactor vessel and significant oxidation of the core graphite and fuel carbonaceous material (e.g., degradation of fuel particle coating layers). Such events have the potential for large releases of fission products from the core, helium pressure boundary, and reactor building, unless SSCs are provided to limit air ingress and limit the magnitude and duration of fission product transport from the reactor building function. If for such events, additional SSCs are needed to ensure that the F-C curve acceptance criteria are met, it is the working group's view that such events should be included as DBAs ,and any additional SSCs needed to meet F-C curve acceptance criteria should be classified as safety-related. The process and criteria to be used for the selection of DBAs to demonstrate compliance with 10 CFR 52.79 are considered Commission policy issues.

SUMMARY OF FINDINGS

The working group believes these issues must be addressed before NRC can endorse the proposed approach to evaluate DBAs.

- As discussed in section 2.1.2 and elsewhere, it is the working group's view that it will be necessary to consider bounding events which would otherwise fall within the BDBE region as design basis events in order to ensure adequate defense-in-depth for containment of fission products, in accordance with regulatory requirements. It is expected that a Commission policy decision will be required if such events are to be excluded from consideration as design basis events.

- The working group believes that additional design information will be required to determine if margins in DBA dose calculations provide adequate conservatism.

2.1.8 LBE Outcome Objective 8 – Event Frequency and Consequence Uncertainties

The LBE white paper states that uncertainty distributions are evaluated for the mean 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 on the LBE frequency straddles two or more regions, 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 for the DBE and DBA consequences must meet regulatory criteria for EAB doses

WORKING GROUP ASSESSMENT

In NUREG -1860, the staff proposed an approach to the treatment of event frequency uncertainties and event consequence uncertainties in establishing the whether the event sequence family should be considered an AOO, DBE, or BDBE. The process proposed by the staff in NUREG-1860 is described in Section 6.4.1 "Probabilistic LBE Selection." The staff's approach made it unnecessary to consider whether the upper and lower bound of the LBE frequency straddled two LBE categories (i.e., regions). The more conservative approach (i.e., higher LBE frequency) would result in an LBE having to meet the same or potentially more restrictive dose criteria than the approach proposed by the NGNP Project. However, the event categorization process proposed by the LBE white paper proposes an additional step to compare the LBE consequences against the consequence acceptance criteria of the more restrictive region, if the upper or lower bound on the LBE frequency straddles two regions.

It is the working group's view that the evaluation approach proposed by the LBE white paper for accounting for uncertainty distributions in the LBEs (i.e., event sequence frequency distributions) in selecting the appropriate category for LBEs (i.e., as and AOO, DBE or BDBE) is reasonable as a guideline. In this regard, the working group views the frequency ranges for categorizing LBEs as guidelines, and not sharp break points in categorizing events. That is, considering a BDBE which falls near the upper frequency boundary for such events could ensure such an event is addressed in an appropriately conservative manner. Any final staff decisions on the adequacy of LBE categorization would be made during the NGNP licensing review.

However, as discussed in the assessment of LBE Outcome Objective 1, it is the working group's view that additional events in the event categories should be selected using deterministic judgment complimented by insights from the NGNP Plant PRA. The categorization of these events should be based on deterministic engineering judgment complimented by risk insights. For example, a rare event which otherwise might be considered a BDBE might be designated as a DBE can to ensure adequate defense-in-depth, as discussed above. Additionally, as discussed in the working group's assessment of LBE Outcome Objective 1, it is the working group's view that the frequency of initiating events and the frequency of the event sequences should be considered in the categorization of events.

Where initiating event frequency is considered in the categorization of events, it is the working group's view that conservative engineering judgment complemented by probabilistic insights should be applied in the event categorization process (e.g., categorizing events involving breaks in piping connected to the helium pressure boundary vessel system).

SUMMARY OF FINDINGS

The working group believes that the basic approach to address frequency and consequence uncertainties appears reasonable. However, the adequacy of the NGNP LBE categorization cannot be evaluated until more design information is provided. As noted previously, the working group also believes deterministic elements of the LBE categorization process should be strengthened.

2.2 Defense-in-Depth Approach

Defense-in-depth is defined in the DID white paper as a safety philosophy which is based on multiple lines of defense, safety margins, and compensatory measures, applied to the design, construction, operation, maintenance, and regulation of nuclear plants to prevent and to mitigate accidents and to assure adequate protection of public health and safety.

The working group notes that the September 10, 2007, Staff Requirements Memorandum on SECY-07-0101 (ADAMS accession number ML072530501) directed the NRC staff to develop a draft policy statement on defense-in-depth for future plants. A future NGNP designer or applicant will be expected to address the provisions of that policy statement if it is approved by the Commission prior to submittal of an NGNP license or design application.

2.2.1 DID Outcome Objective 1 – Adequacy of Defense-in-Depth Definition

The proposed risk-informed and performance-based framework for DID has three major elements: Plant Capability Defense-in-Depth, Programmatic Defense-in-Depth, and Risk-Informed Evaluation of defense-in-depth. These elements are viewed as complementary in assuring that a design is tolerant to uncertainties in knowledge of plant behavior, component reliability, or operator performance that might compromise safety.

Plant Capability Defense-in-Depth is intended to assure that the designer has incorporated multiple lines of defense in designing the functional capability of the physical plant, including conservative design approaches for the barriers and systems, structures, and components performing safety functions associated with the prevention and mitigation of accidents.

Programmatic Defense-in-Depth is intended to assure that the programmatic actions for designing, constructing, operating, testing, maintaining, and inspecting the plant are adequate in ensuring that the plant capabilities are maintained throughout the life of the plant.

The Risk-Informed Evaluation of defense-in-depth is intended to be a structured, logical process for assessing the adequacy and sufficiency of the plant capabilities and programmatic defense-in-depth, based on risk insights gained from the use of PRA in defining LBEs, and identifying the roles of SSCs in the prevention and mitigation of accidents, as well as in addressing uncertainties.

WORKING GROUP ASSESSMENT

The NGNP RIPB working group agrees with the high level definition of DID as "a safety philosophy which is based on multiple lines of defense, safety margins, and compensatory measures, applied to the design, construction, operation, maintenance, and regulation of nuclear plants to prevent and to mitigate accidents and to assure adequate protection of public health and safety" (Section 3.2.1). An instructive discussion of the DID philosophy also appears in the Fukushima Near Term Task Force Report[6], which describes DID as encompassing the following criteria:

1. require the application of conservative codes and standards to establish substantial safety margins in the design of nuclear plants;

2. require high quality in the design, construction, and operation of nuclear plants to reduce the likelihood of malfunctions, and promote the use of automatic safety system actuation features;

3. recognize that equipment can fail and operators can make mistakes and, therefore, require redundancy in safety systems and components to reduce the chance that malfunctions or mistakes will lead to accidents that release fission products from the fuel;

4. recognize that, in spite of these precautions, serious fuel-damage accidents may not be completely prevented and, therefore, require containment structures and safety features to prevent the release of fission products; and

5. further require that comprehensive emergency plans be prepared and periodically exercised to ensure that actions can and will be taken to notify and protect citizens in the vicinity of a nuclear facility.

Of the above criteria, the working group is not clear regarding the NGNP approach to the fourth criterion. NRC's regulations address this criterion in the requirements for evaluation of a hypothetical accident in 10 CFR 50.34 and 10 CFR 52.79, as discussed in the LBE white paper assessment above. This regulatory requirement is predicated on the potential for severe events that could result in release of appreciable quantities of fission products from reactor fuel. The regulatory requirement is imposed to assure that mitigation of consequences, as well as prevention of these very low probability but high consequence events, are appropriately considered as part of the DID measure in the safety design of a nuclear plant.

While the DID white paper correctly notes that the LWR severe accident definition is not applicable to HTGRs, the working group believes that a severe accident definition more

[6] "Recommendations for Enhancing Reactor Safety in the 21st Century, The Near-Term Task Force Review Of Insights From The Fukushima Dai-Ichi Accident", July 2011, ADAMS accession number ML11861807.

pertinent to a HTGR could be severe core or fuel damage resulting from a very low probability event and consequent release of a significant quantity of radionuclides from fuel. The NGNP Project's assertion that HTGR bounding source terms are calculated for a spectrum of BDBEs that are of comparable likelihood to those of LWRs (i.e., >1E-6 per reactor year) may not provide adequate DID in this regard. The MST white paper seems to convey the message that for all BDBEs considered in that the white paper, the peak fuel temperature does not rise significantly. It is not clear, however, what "comparable likelihood" means in this context.

DID for NGNP is intimately related to several other white paper topics, e.g., LBE selection (discussed above), safety classification and treatment of SSC, mechanistic source term, and PRA. The NGNP Project's proposed approach to selecting the LBEs using deterministic judgment complemented by the NGNP PRA is, in theory, reasonable to the working group. However, as mentioned elsewhere in this assessment report, the approach does not describe in detail how initiating events will be identified deterministically for NGNP. Pending further details of such an approach, it is not possible for the working group to make a preliminary assessment of the adequacy of the DID approach insofar as selection of LBE is concerned with regard to inclusion of "severe accidents," and insofar as a proper assessment of bounding source terms is concerned. The working group believes that a conservative deterministic selection of LBE could ensure adequate DID for the NGNP prototype.

The concept of risk metrics is an important consideration in assessing the adequacy of the DID approach for NGNP. The DID white paper states that the conventional risk metrics, such as core damage frequency as used in the context of LWRs, are not applicable to NGNP. Instead, the white paper and the response to RAI DID-1 suggest that the specific risk metrics to be used for the NGNP plant will be a product of PRA, and will consider the following factors to ensure that an adequate set of controls for public protection and defense in depth is provided:

- The release categories will be sufficient to address the integrated risk of a multiple reactor module facility.

- Some release categories will involve source terms from two or more reactor modules and others will involve releases from non-core sources of radioactive material such as the spent fuel storage.

- Risk metrics will include event sequence frequencies associated with LBEs and release categories, as well as a quantification of the offsite radiological consequences to facilitate comparisons to the top-level regulatory criteria (TLRC) and to the quantitative health objectives (QHOs).

- Risk significance will be defined in terms of release category frequencies and will meet the requirements of the supporting PRA standards. Risk significance will also address the margins relative to the TLRC and QHOs.

- The risk metrics used in typical LWR PRA applications such as core damage frequency (CDF) and large early release frequency (LERF) are based on Level 1 PRAs with modest extensions in the Level 2 domain to address LERF.

- For the NGNP PRA it is more useful to compare against the risk metrics of a full scope Level 3 PRA for an LWR rather than evaluate at an intermediate level that is LWR-specific.

The above statements are further elaborated in the PRA white paper though the latter does not provide, in the view of the working group, a clear definition of risk metrics for NGNP. The working group makes the following observations in this regard:

- Risk metrics are expected to include event sequence frequencies associated with LBEs that would result in bounding source terms.
- A consensus PRA standard, which is essential for assessing the risk significance, has yet to be approved.
- A full-scope Level 3 PRA, which is essential for establishing the NGNP risk metrics, has not yet developed.

In RAI DID-13, the working group sought clarification of the role of cross-cutting issues such as emergency planning, and design codes and standards. The response to this RAI provided additional description of these cross-cutting elements. Based on the information provided in the RAI response, the working group agrees with the NGNP approach that selection of codes and standards supports both the plant capabilities for DID and the programmatic DID. Likewise, the working group agrees that emergency planning is also a cross-cutting element in that includes elements of plant capabilities DID as well as programmatic DID.

The working group notes that the NGNP DID approach describes multiple concentric barriers to fission product release concept akin to LWR multiple barriers, but does not elaborate on the containment functional performance issue as part of this barrier concept. Containment functional performance is not an issue addressed by the white papers within the scope of this assessment.

SUMMARY OF FINDINGS

Demonstrating the adequacy and sufficiency of the proposed DID approach requires a thorough understanding of and proper implementation of event selection (including a stronger deterministic element, as discussed in the assessment of the LBE white paper), safety classification and treatment of SSCs, source term, emergency planning, and scope and applicability of PRA methodologies (including risk metrics). In the absence of detailed design information on these topics at this point in time, it is premature to make more definitive conclusions on the adequacy and sufficiency of the details of the proposed DID approach. Such conclusions would be the result of detailed NRC staff review of a specific detailed NGNP design, perhaps in a topical report which could be reviewed prior to receipt of a license application.

2.2.2 DID Outcome Objective 2 – Appropriate Plant Capability

The DID white paper describes Plant Capability DID as reflecting the decisions made by the designer to incorporate defense-in-depth into the functional capability of the physical plant. These decisions include the use of multiple barriers, diverse and redundant means to perform safety functions to protect the barriers, conservative design approaches for the barriers and SSCs, safety margins, siting and other physical and tangible elements of the design that use multiple lines of defense to protect the public. The decision making is systematically evaluated in a risk-informed manner by using PRA and a parallel set of deterministic evaluations. The PRA is based on plant design, including specification of the capabilities of the plant SSCs

The results of the PRA are dependent on the safety margin and reliability of each SSC modeled in the PRA. The reliability of the SSCs responsible for the Plant Capability DID is to be assured by their design and by the elements of Programmatic DID. The PRA and the parallel deterministic evaluations include, as part of the modeling and quantification of the scenarios, models of the plant capabilities, and how the plant is operated and maintained under the programmatic controls. Information from the PRA and the deterministic evaluations is used to support the design, provide input to the formulation of process requirements, and provide information to evaluate the adequacy and sufficiency of the defense-in-depth strategies. The PRA also provides critical input to the identification and evaluation of the uncertainties that are addressed in the Plant Capability and Programmatic DID elements.

WORKING GROUP ASSESSMENT

The Plant Capability DID is founded on a number of important DID principles. The framework appears to be logical; however, several items of the framework defer more substantial discussion to the license application stage, which limits the working group's ability to assess the proposal. For example, the NGNP safety design claims to include multiple robust barriers to radioactive material release. However, independence of barrier concept and challenges to barrier integrity cannot be addressed until the PRA and other detailed design information are submitted to support the license application. Additional information regarding the approach for each of the plant capability DID principles can be provided during pre-application interactions with a prospective licensee to ensure their proper consideration as the design is developed.

The working group notes that all three major components of the approach described in the DID white paper (i.e., plant capability, programmatic, and risk-informed evaluation) have specific roles to play in addressing uncertainties. The DID white paper and related documents claim that uncertainties in the definition of LBEs and safety classification of SSCs are explicitly taken into account in defining the plant capabilities for DID. However, lacking more information regarding the specific NGNP design, it is not possible to determine how the uncertainties are accounted for. This topic is addressed in the LBE white paper discussion above.

The working group also notes that the definition of adequate plant capability is highly dependent on conservative LBE selection. The working group believes that the findings associated with that topic should be addressed to ensure adequate defense-in-depth.

SUMMARY OF FINDINGS

It is the working group's preliminary assessment that the definition of Plant Capability appears adequate. However, it cannot be concluded that this definition will yield an acceptable outcome until detailed design information is provided for NRC review.

2.2.3 DID Outcome Objective 3 – Appropriate Programmatic Capability

The DID white paper describes Programmatic DID as reflecting the programmatic actions for designing, constructing, operating, testing, maintaining, and inspecting the plant so that there is a greater degree of assurance that the defense-in-depth factored into the plant capabilities during the design stage is maintained throughout the life of the plant. The NGNP Project approach to Programmatic DID includes the application of conservative safety margins and deterministic elements in the definition of the F-C Curve, selection of LBEs, safety classification of SSCs, and formulation of special treatment requirements for the safety classified SSCs.

As in the case of Plant Capabilities Defense-in-Depth, the decision making for Programmatic Defense-in-Depth is systematically evaluated in a risk-informed manner by using PRA and a parallel set of deterministic evaluations. The PRA and the parallel deterministic evaluations include, as part of the modeling and quantification of the scenarios, how the plant is operated and maintained under the programmatic controls. The PRA also provides critical input to the identification and evaluation of the uncertainties that are addressed in the Programmatic Defense-in-Depth elements.

WORKING GROUP ASSESSMENT

The scope of topics covered by the Programmatic DID element appears to be reasonable, with the exception of measures to address catastrophic events, as discussed below. The efficacy of the programs is indeterminate at this point in time, given the lack of specific information about those programs. Therefore, no conclusions can be made until specific programs are proposed by a license applicant, and reviewed and approved by the NRC staff. For example, some non-safety-related SSCs are expected to have special treatment to provide DID. As discussed in the SSC white paper assessment below, it is not clear how the appropriate treatment will be identified and applied for this purpose, and that is difficult to quantify the effects of treatment in a PRA. The working group believes that conservative engineering judgment is needed to ensure the adequacy of treatment of SSCs providing DID.

It is also the working group's view that the scope of programmatic DID topics does not adequately consider programmatic elements for managing catastrophic events. Especially in view of related recommendations from the NRC's near-term review of insights from the Fukushima Dai-Ichi accident (e.g., Recommendation 8),[7] the working group believes that the Project should give broader consideration to how such programmatic DID measures as emergency operating procedures (EOPs), severe accident management guidelines (SAMGs), and extensive damage mitigation guidelines (EDMGs) are applied to limit the progression and consequences of hypothetical catastrophic events (i.e., severe accident or security events beyond the design basis).

Hypothetical events resulting in major damage to both the primary loop and the reactor building may be among the catastrophic events deterministically selected and mechanistically analyzed in this DID context for modular HTGRs. As suggested by the working group in its RAI ARP DD-6, events leading to massive ingress of air or oxygen[8] into the primary system may call for programmatic DID coping measures and mitigation strategies aimed at terminating air/oxygen ingress into the damaged reactor building and reactor system. By acting to limit the amount of oxygen that enters the reactor building and from there the primary system, the goal of such measures would be to prevent or limit the radioactive releases that could otherwise result from the exothermic oxidation of structural and core graphite and the eventual heat-up and oxidation induced failure of TRISO coated fuel particles. Among the factors considered in evaluating such DID coping measures and mitigation strategies would be the time available for implementation.

[7] "Recommendations for Enhancing Reactor Safety in the 21st Century," NRC Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident (ADAMS accession number ML111861807)
[8] NUREG/CR-6944, "NGNP Phenomena Identification and Ranking Tables (PIRTs), Volume 6: Process Heat and Hydrogen Co-Generation PIRTs," highlighted ground hugging plumes of cold oxygen as posing potentially significant hazards to the reactor plant from events at co-located process heat user facilities.

The NGNP Project's September 15, 2010, response to RAI ARP DD-6 cited the DID white paper's listing of several potentially relevant programmatic DID elements, including EOPs and SAMGs. The response further noted, as stated in DID white paper section 3.2.3, that such strategies will be developed in the context of the NGNP approaches to using PRA, selecting LBEs, and classifying and treating SSCs. The working group notes, however, that catastrophic events appropriate to this DID element are not addressed in the LBE white paper. The regulatory context for such considerations is expected to become clearer as guidance and regulations evolve in response to Fukushima task force recommendations and other relevant insights.

SUMMARY OF FINDINGS

The working group believes that programmatic DID should be strengthened to address mitigation of hypothetical events.

2.2.4 DID Outcome Objective 4 – Acceptable Balance of Deterministic and Probabilistic Criteria

The DID white paper states that the Plant Capability Defense-in-Depth and the Programmatic Defense-in-Depth elements are combined in the Risk-Informed Evaluation element in a manner that is intended to provide an acceptable balance between the deterministic and the probabilistic safety evaluations that will be performed to support the NGNP licensing application. The strategies for preventing and mitigating accidents including the roles of SSCs are identified and evaluated in Risk-Informed Evaluation of defense-in-depth, based in part on a review of the PRA results. Prevention and mitigation are defined with respect to limiting the release of significant amounts of radioactive material as a result of event sequences selected for a given design. Finally, the balanced use of deterministic and probabilistic evaluations is intended to provide a logical process to establish the adequacy and sufficiency of defense-in-depth for the NGNP Project.

WORKING GROUP ASSESSMENT

The DID white paper and related submittals describe the intent to integrate PRA into the NGNP design process at an early stage. Integrating PRA into the design process may be interpreted as using PRA to perform LBE selection, SSC classification, etc. Alternatively, it may mean traditional deterministic analysis for the purpose complemented, as appropriate, by PRA. That is to say that PRA is used to refine the otherwise deterministically selected LBEs, based on a more rigorous approach to SSC reliability, etc. The adequacy and quality of PRA must be assured if it is to be relied upon for LBE selection and SSC classification. Absent that, it will be prudent to consider some deterministically selected bounding events and to assure adequate safety margins.

The DID white paper states that derivation of the F-C curve included consideration of defense-in-depth. Specifically, dose criteria embodied in the TLRC and the F-C curve are lower than the surrogate dose criteria associated with the NRC's Safety Goal Quantitative Health Objective (QHO) for prompt fatality risk. The DID white paper further states that experience has shown that designs which meet the TLRC, and include appropriate design and analysis margins, including defense-in-depth, also meet the Safety Goal, often by orders of magnitude.

As stated above in the working group's assessment of the LBE outcome objective 3, it is the working group's view that BDBEs should include event sequences or initiating events with mean frequencies down to 1E-7 per reactor-year, which provides a reasonable cutoff for assessing whether the NGNP meets the NRC safety goals. The staff believes that it is a Commission policy issue on whether LBE sequences below the lower frequency cutoff for the DBE region (i.e., 1E-5 per reactor-year) can be excluded from the accidents considered in developing the NGNP siting source term for which 10 CFR 52.79 dose criteria would apply.

SUMMARY OF FINDINGS

As discussed above, in the LBE white paper assessment, the working group believes the proposed approach should be strengthened by incorporation of additional deterministic elements.

2.2.5 DID Outcome Objective 5 – Adequacy of Information To Be Provided

The DID white paper states that the following set of information should provide sufficient information for the NRC to judge the adequacy of the DID provisions:

a) A definition of defense-in-depth that is appropriate for the NGNP Project.

b) The roles of each barrier to radioactive material retention for each significant inventory of radionuclides in providing the plant capabilities for defense-in-depth.

c) How the reliability, capability, and independence of each barrier are defined and evaluated in terms of their plant capabilities for defense-in-depth.

d) How the safety functions are defined and how they support the integrity of each barrier in providing the plant capabilities for defense-in-depth.

e) The roles of diverse combinations of inherent and passive design features and SSCs that are used as well as active engineered systems to perform the safety functions as part of the plant capabilities for defense-in-depth.

f) How the reliability, capability, and independence of each SSC providing a safety function is defined and evaluated as it relates to the plant capabilities for defense-in-depth.

g) How the principles of design margins, redundancy, diversity, and independence have been applied in providing the plant capabilities for defense-in-depth.

h) An appropriate definition of accident prevention and mitigation and a means to evaluate the impact of the defense-in-depth strategies on maintaining acceptable risk levels.

i) The roles and effectiveness of specific barriers and SSCs in the prevention and mitigation of accidents.

j) The role design safety margins reflected in the applied codes and standards play in providing a robust design with defense-in-depth.

k) How compensating measures and other aspects of Programmatic Defense-in-Depth are applied to address uncertainties.

l) How a set of deterministic principles derived from the regulatory foundation is applied in the risk-informed evaluation of the adequacy and sufficiency of defense-in-depth for the NGNP Project.

m) How the elements of the safety design approach are used to evaluate plant design features in an integrated manner as part of an overall risk management approach in which risk analysis is used to improve operational and engineering decisions broadly by identifying and taking advantage of opportunities to reduce risk.

WORKING GROUP ASSESSMENT

The scope of topics covered in DID Outcome Objective 5 appears to the working group to be reasonable. However, in the absence of NGNP design-specific information on these topics at this point in time, it is premature for the working group to make any conclusions on the adequacy and sufficiency of the details intended to be covered in the proposed topics. Such conclusions would be the result of detailed NRC staff review of a specific detailed NGNP design, perhaps in a topical report which could be reviewed prior to receipt of a license application. Such a review would determine whether the proposed approach demonstrates compliance with regulatory requirements.

SUMMARY OF FINDINGS

While the scope of topics addressed by this outcome objective appear to be reasonable, additional design information will be required to assess the adequacy of their implementation.

2.3 Structures, Systems, and Components Safety Classification

The SSC white paper describes a proposed approach to classify structures, systems, and components according to their safety significance, with the intent of focusing resources on the most significant SSCs.

2.3.1 SSC Outcome Objective 1 – Acceptable Approach

The SSC white paper requests that the NRC agree with its first outcome objective, which is stated as follows:

> The NGNP approach to risk-informed safety classification and special treatment that blends the strengths of probabilistic and deterministic methods is acceptable.

The SSC white paper states that the NGNP fuel will be classified as safety-related since it is the most important barrier to the release of radionuclides to the environment. The paper also states that the SSCs that ensure safe shutdown of the NGNP reactor will also be classified as safety-related. Additional SSCs designated as safety-related will include: (1) SSCs that are relied on to perform “required safety functions” to prevent or mitigate the consequences of DBEs so the DBE dose consequence complies with the TLRC for DBEs; and (2) SSCs that are relied on to perform required safety functions to prevent the frequency of beyond design basis events (BDBEs), with consequences greater than the dose limits of 10 CFR 50.34, from increasing into the DBE region. The NGNP designer will select the specific safety-related SSCs to meet these two criteria.

The SSC white paper states that the selection of safety-related SSCs is to begin by identifying the safety functions that are required (i.e., "required safety functions") for each DBE to meet the DBE TLRC, which are derived from the 10 CFR Part 100 dose guidelines as described in the LBE white paper discussion above. To meet the DBE TLRC, required safety functions will generally include: reactor shutdown, removal of core heat and containment of radionuclides, and control of chemical attack (e.g., fuel oxidation, graphite oxidation). For each DBE, the NGNP SSCs that are provided to perform each required safety function are reviewed to determine which SSCs have sufficient capability and reliability. By considering the SSCs that can perform each required safety function for each DBE, a set of SSCs, that can provide the required safety functions with the required capability and reliability for all DBEs, are selected and classified as safety-related. The SSCs selected by the designer to be safety related are expected to be generally passive rather than active SSCs, such as the SSCs involved in passive accident core heat removal and the passive radionuclide barriers such as the fuel. These safety-related SSCs are to be provided with a full range of special treatment to ensure that the SSCs have the needed capability and reliability to perform the required safety functions. The NGNP DBA sequences are defined as the DBE accident sequences with only the safety-related SSCs assumed to be available (i.e., credited) for prevention and mitigation.

The SSC white paper states that the process for selecting safety-related SSCs continues by analyzing each BDBE with all the plant SSCs modeled in the plant PRA. The SSC reliabilities and availabilities are assumed to be consistent with those assumed in the NGNP PRA. If a BDBE is found to meet the BDBE dose consequences acceptance criteria but has a dose consequences that is above the DBE dose consequence acceptance criteria (i.e., 10 CFR Part 100 guidelines) assurance is to be provided that the BDBE frequency remains below the lower frequency cutoff of the DBE region. That is, any BDBE sequence which has a dose consequence that is higher than the dose limits in 10 CFR 52.79[9] is reviewed to determine the safety functions that are required to prevent the frequency of the BDBE from increasing into the DBE region. The SSCs that are available and sufficient to perform the required functions to keep the frequency of the BDBE from increasing into the DBE region are identified. The SSCs that are selected to perform these safety functions are classified as safety-related.

The SSC white paper also defines a category of SSCs that are non-safety-related with special treatment, or NSRST. These SSCs are defined as SSCs relied upon to perform safety functions to:

- mitigate the consequences of AOOs to comply with the TLRC

- prevent the frequency of DBEs with consequences greater than the 10 CFR 20 offsite dose limits from increasing into the AOO region.

The NGNP Project notes that special treatments can enhance the capability as well as the reliability of NSRST SSCs, thereby shifting the locations of the LBEs on the frequency versus dose chart (i.e., reduce the frequency of the LBE and/or reduce the dose consequences of the LBE).

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[9] Similar to the other papers discussed in this assessment, the SSC white paper refers to 10 CFR 50.34. The proper regulatory citation is to 10 CFR 52.79 for a combined license application. However, as noted previously, the dose requirements of these two regulations are identical.

WORKING GROUP ASSESSMENT

The SSC white paper has described an approach to classifying and treating SSCs that includes specific criteria for specifying safety-related SSCs, assesses SSCs against the criteria in a risk-informed manner and provides defense-in-depth through identification of non-safety-related SSCs that will receive treatment to assure capability and reliability are consistent with assumptions in the PRA. The NRC is generally supportive of a risk-informed approach to classifying SSCs and determining appropriate levels of treatment for the SSCs under different classifications. Such an approach is currently available to operating reactor licensees through voluntary application of the requirements in 10 CFR 50.69, though no licensee has taken advantage of this rule as of the date of this report. Also, the recent staff requirements memorandum (SRM) on SECY-11-0024, "Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews," dated May 11, 2011, directed the NRC staff to complete a feasibility study for using risk information in categorizing SSCs as safety-related or non-safety-related for the design-specific Small Modular Reactor (SMR) review plans. The staff's response to the SRM discusses long-term activities that the NRC can implement to enhance the use of risk insights in categorizing SSCs for Small Modular Reactors. The NRC's long term activities may include a pilot study to test the concepts of developing a new, risk-informed regulatory framework, described in SECY-11-0024, dated February 18, 2011, and NUREG 1860, "Feasibility Study for a Risk-Informed and Performance-Based Regulatory Structure for Future Plant Licensing," Volumes 1 and 2, issued December 2007.

SUMMARY OF FINDINGS

While the working group generally supports the NGNP's use of a risk-informed approach to classifying SSC's, the working group is not able to conclude that the proposed risk-informed approach to classification and treatment of SSCs is reasonable. The basis for this conclusion is summarized below.

1. A major feature of defense-in-depth philosophy is maintaining multiple barriers to the release of fission products. Therefore, the NGNP criteria for determining safety-related SSCs should address all of the barriers included in the design to prevent or limit the release of radioactivity to the environment, not just the fuel as described in the SSC white paper. In addition, the definition of safety-related SSCs should make clear that SSCs required to assure that the primary barriers are intact are designated as safety-related.

2. The NGNP criteria for determining safety-related SSCs should be stated in a fashion similar to the definition of safety-related structures, systems and components in 10 CFR 50.2 and should be equivalent, in principal, to this definition. In this regard, the working group notes that the NRC staff and current reactor licensees have considered the term design basis events referred to in 10 CFR 50.2 to include Anticipated Operational Occurrences.

3. NGNP's specification of treatment for select non-safety-related SSCs to assure a measured degree of reliability and capability as a means of incorporating defense-in-depth is incomplete, as discussed below in section 2.3.2 and 2.3.4.

4. While the proposal provides an extensive outline of the planned approach, there is not sufficient information regarding the NGNP design or details of how the approach will be implemented to support a conclusion that it will yield an acceptable outcome. However,

the working group acknowledges that a risk-informed, performance-based approach can result in an acceptable design, if it is properly implemented. For example, the SSC white paper does not describe how the Commission's policy on regulatory treatment of non-safety systems (RTNSS) will be implemented for NGNP.

2.3.2 SSC Outcome Objective 2 – Acceptable Classification Categories

The second SSC white paper outcome objective is described as:

> The NGNP risk-informed safety classification categories and the bases for SSC classification within each category are acceptable.

The SSC white paper states that the NGNP Project has adopted the 10 CFR Part 52 COL application process recommended in the Licensing Strategy Report as the foundation for the NGNP licensing strategy. The NGNP Project has proposed to classify the NGNP SSCs into one of two basic safety categories. These safety categories are safety-related (SR) and non-safety-related (NSR).

SSCs which are classified as SR are to be given the full scope of special treatment. Special treatment would include such aspects as design requirements to ensure that the SSC is capable of performing its safety function during the most severe conditions of the LBE, design requirements to ensure that the SSC is provided with safety margin and design conservatism, as well as technical specification requirements, ISI requirements, IST requirements and QA requirements, along with other regulatory requirements.

SSCs classified as safety-related form the set of SSCs that are necessary and sufficient to prevent or mitigate DBEs from exceeding the TLRC for DBEs. Additionally, any LBE in the BDBE region which has a dose consequence above 10 CFR Part 100 dose guidelines is reviewed to determine which safety functions and associated SSCs would be needed to prevent the frequency of the BDBE from increasing into the DBE region. For any such BDBE, a sufficient set SSCs that can perform these safety functions is identified. The SSCs in this set are classified as safety-related, if not previously selected to be safety-related. The NGNP Project states that deterministic engineering judgment has been applied by designating the NGNP fuel as SR and designating SSCs needed to safely shutdown the NGNP reactor as SR.

The SSC white paper states that SSCs classified as NSR are to be provided with special treatments which are commensurate with their safety-significance. NSR SSCs which meet criteria discussed in section 2.3.1 above are designated as non-safety-related with special treatment (NSRST). NSRST SSCs are to be provided with less than the full scope of special treatment, with special treatment commensurate with the safety importance and the required capability and reliability of the SSC modeled in the NGNP PRA. A non-safety-related SSC may have no special treatment if it is not important with respect to preventing or mitigating any LBEs.

WORKING GROUP ASSESSMENT

Categories for Classification

The SSC safety classifications for the NGNP project are in effect: safety-related, non-safety-related without special treatment, and non-safety-related with special treatment. SSCs which are classified as safety-related are to be given the full scope of special treatments. Some SSCs which do not meet the criteria for a safety-related classification may play a back-up safety role and therefore will receive special treatments which are commensurate with their safety-significance. A non-safety-related SSC may have no special treatments if it is not important with respect to preventing or mitigating any LBEs.

The working group finds that the three category approach proposed for the NGNP project is reasonable. Similar approaches have been used for certification of passive reactor designs and licensing applicants that have referenced those designs. In addition, the NRC expects to use a graded approach for review of applications for certification and licensing of integral pressurized water reactor designs. However, the bases for SSC classification within each category, as discussed in the white paper are not reasonable for the reasons discussed below.

Treatment of Barriers to the Release of Radioactivity

The safety-related classification is reasonable to the extent that it is consistent with existing regulations, but it appears to be incomplete. As noted in section 2.3.1 above, the classification proposed by the SSC white paper should clearly address all barriers included in the design to prevent or limit fission product releases to the environment.

Comparing 10 CFR 50.2 and 10 CFR 50.49(b) with the proposed basis for classifying SSCs as SR indicates that some aspects of the proposal appear to be consistent with the regulations while other aspects appear not to be consistent. For example, for LWRs, it is regulatory practice to not only require SSCs to be SR if they are needed assure reactor coolant pressure boundary (RCPB) integrity, but also require the RCPB itself be safety-related. Although not explicitly stated by the NGNP Project, it is the working group's view that the SSCs which comprise the NGNP primary helium pressure boundary (HPB) (e.g., primary vessel system, connected piping, valve bodies, etc.) should be classified as safety-related, and have sufficient capability and reliability to perform the required radionuclide containment safety function. The working group believes that for DBEs, this approach is consistent with requirements that the NGNP primary helium pressure boundary be highly reliable in both preventing the initiation of DBE sequences, and to be highly reliable in mitigating the dose consequences of DBE sequences so that the DBE dose consequences meet the TLRC. The classification of the primary HPB SSCs as safety-related is also viewed as an outcome of the proposed process described by the NGNP Project for the selection of safety-related SSCs. The working group also believes that requiring the NGNP primary helium pressure boundary SSCs to be safety-related is consistent with the staff's earlier views documented in a March 26, 2002, letter from NRC to Exelon (ADAMS accession number ML020860097) in which the staff stated that SSCs relied on to avoid exceeding TLRC or to keep the frequencies of similar event sequences within the acceptable range (e.g., within the AOO, DBE, or EPBE ranges) should be classified as safety-related.

Similarly, SSCs associated with the NGNP reactor building containment should be classified as safety-related with special treatment if the SSCs are relied on to avoid exceeding TLRC for a DBE, or if the SSCs are relied on to prevent the frequency of a BDBE with a dose consequence greater than the dose limits of 10 CFR 50.34 from increasing into the DBE region. The working group agrees that special treatment requirements for the safety-related SSCs should address the need to ensure that the safety-related SSC's are capable of performing their safety functions under the safety-related design conditions (i.e., limiting service conditions under which the SSCs are required to perform their safety-related functions).

It is the working group's view that the safety-related SSCs that provide the principle barriers to the release of fission products (i.e. NGNP fuel, primary HPB) should have appropriate special treatment requirements in the form of engineering safety and design limits (i.e., fuel safety and design limits, HPB safety and design limits) and that NGNP safety analyses should demonstrate that these safety and design limits are not exceeded for any AOO.

SSCs for Mitigation of BDBE included in Analysis of Site Suitability

It is the working group's view that to the extent the Commission may require events in the BDBE frequency region to be included in the accident source term for purposes of evaluating site suitability (i.e., 10 CFR Part 100) the SSCs relied on to perform required safety functions to prevent or mitigate the consequences of BDBEs to comply with 10 CFR Part 100 should be safety-related. As noted by the SSC white paper, NGNP SSCs will need to conform to the ASME Code requirements that are not yet developed, as well as existing ASME Code requirements which are applicable and adaptable to the NGNP.

Treatment of AOOs

The definition of "design basis events" set forth in 10 CFR 50.49(b), as conditions of normal operation, including anticipated operational occurrences, design basis accidents, external events and natural phenomena, and the historical interpretation of the term "design basis events" in 10 CFR 50.2 are broader than the definition of "design basis events" proposed by the NGNP Project. As such, 10 CFR 50.49(b) would require that SSCs involved in the prevention and mitigation of AOOs should also be safety-related, which is regulatory practice for LWRs. However, the NGNP project proposes that SSCs that are relied upon to perform safety-functions to mitigate the consequences of AOOs to meet the associated TLRC, be classified as NSRST. SSCs involved in the prevention and mitigation of AOOs are also expected to include SR SSCs such as the fuel and the HPB. NSR SSCs involved in the mitigation of AOOs are anticipated to include operational SSCs such as operational core cooling systems and operational waste treatment systems (e.g., clean-up and filtration systems).

It is regulatory practice for LWRs that those SSCs credited with prevention and mitigation of AOOs are designated (using deterministic judgment) as SR to ensure the integrity of the principle fission product barriers (e.g., fuel barrier, and RCPB barrier) rather than to ensure that 10 CFR Part 20 limits are met. The NRC Standard Review Plans for AOOs do not include a review of radiological consequences because events designated as AOOs are not expected, by design, to result in release of radioactivity that might challenge regulatory limits. NGNP has not provided an adequate rationale for their proposal to treat AOOs differently (i.e., be subject to event-based dose limits). As noted in Section 2.1.4 above, the working group considers AOO dose acceptance criteria to be a potential Commission policy issue.

The NGNP further states that SSCs relied upon to perform safety functions to prevent the frequency of DBEs with consequences greater than 10 CFR Part 20 offsite dose limits from increasing into the AOO region are to be classified as NSRST. The NRC staff stated in its review of the proposed risk-informed licensing approach for the Pebble Bed Modular Reactor (PBMR)[10] that SSCs which are relied upon to prevent the frequency of an LBE from increasing from a lower event category (e.g., DBE) to a higher event category (e.g., AOO) should be categorized as SR. The working group believes that this previous position is also applicable to the NGNP risk-informed licensing approach.

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[10] "NRC Staff's Preliminary Findings Regarding Exelon Generation's (Exelon's) Proposed Licensing Approach For The Pebble Bed Modular Reactor (PBMR)," March 26, 2002, ADAMS accession number ML020860097)

The working group notes that the scheme proposed by the NGNP Project creates the possibility that a NSRST SSC mitigating an AOO could have higher safety significance than a safety-related SSC mitigating a DBE. That is, the consequences of an AOO could lie closer to an iso-risk contour (defined as a curve of constant risk, equal to the product of the frequency and consequence of an event) than the consequences of a DBE. If the degree of special treatment for an SSC is to be commensurate with its safety significance, it is inappropriate that a lesser degree of special treatment be assigned to an SSC mitigating such an AOO. Therefore, the working group does not agree with the bases proposed for the NSRST classification.

SUMMARY OF FINDINGS

The working group is not able to conclude, at this time, that the second Outcome Objective has been met, i.e., that the bases for SSC classification within each category are reasonable.

- The classification categories should clearly address all fission product release barriers, including the helium pressure boundary and the reactor building.

- SSCs mitigating events in the BDBE region may need to be safety-related.

- SSCs will need to conform to ASME Code requirements, which have yet to be established.

- The SSC white paper does not provide an adequate justification for the proposed NSRST classification.

<u>2.3.3 SSC Outcome Objective 3 – Special Treatment of Safety-related SSCs</u>

The third SSC white paper outcome objective is stated as:

> The special treatment for the SR category of classification is commensurate with ensuring the SSCs ability to perform their safety function for DBEs and high consequence BDBEs.

The SSC white paper proposes that the fuel and SSCs that ensure safe shutdown be classified as SR. The paper also proposes that SSCs relied on to perform required safety functions to prevent or mitigate the consequences of DBEs to comply with the TLRC and SSCs relied on to perform required safety functions to prevent the frequency of BDBEs with consequences greater than the 10 CFR 50.34 dose limits from increasing into the DBE region also be classified SR. SSCs which are classified as SR are to be given the full scope of special treatments. As noted earlier special treatments would include such aspects as: design requirements to ensure that the SSC is capable of performing its safety function during the most severe conditions of the LBE; design requirements to ensure that the SSC is provided with safety margin and design conservatism, as well as, technical specification requirements, ISI requirements, IST requirements and QA requirements, amongst others. Specific treatment requirements will be determined as part of the deterministic safety analysis.

WORKING GROUP ASSESSMENT

It is the working group's view that the full scope of special treatment requirements for the SSCs classified as SR should be established to ensure that the SSCs have the capability and capacity to perform their required safety functions. In this regard, safety-related SSCs will be subject to safety-related design conditions (i.e., temperatures, stresses, heat loads) that safety-related SSCs must meet for each DBE. The design, fabrication, and operational requirements needed for the safety-related SSCs to have the needed capability and reliability are dependent on LBE sequences for which they must perform and would be reviewed and assessed as part of the NGNP licensing application review. In this regard, it is expected that the NGNP design will include a number of SR SSCs with innovative design aspects such as the fuel, passive decay heat removal, and safe shutdown components. As such, it is expected that these features will involve new and innovative special treatment aspects (e.g., fuel qualification program, reactor cavity coolant system (RCCS) testing). The special treatment requirements of these SR SSCs would be evaluated by the NRC staff as part of the NGNP license application review.

The SSC white paper description of special treatment states that the reliability and capability of SR SSCs are derived from the frequency and consequences of the LBEs that those SSCs mitigate. This description is incomplete, because frequency and consequences do not account for equipment's ability to function adequately in the environmental conditions it may be subjected to in the event of an accident, ability to withstand a seismic event, or other performance attributes unrelated to the frequency and consequences of the event. While Table 1 in the SSC white paper appears to recognize these additional factors, the SSC white paper text appears to be incomplete, because it implies a more limited set of special requirements. In its response to RAI SSC-9, INL proposed a revision to the SSC white paper which states that the LBE definition will define the loading conditions and environmental conditions, including any harsh environments, under which the SSC must fulfill its safety function(s), and this will facilitate a full definition of the special treatment requirements. The working group reviewed the proposed revision to the White Paper and finds that it resolves the concerns identified in RAI SSC-9.

The NGNP approach involves using both the PRA and the FSAR safety analyses to identify the capability and reliability requirements that must be met through special treatment. The approach acknowledges that aspects of LBEs other than event frequency and event consequences (e.g., performance in an adverse environment) must be addressed with special treatment. The SSC white paper listed the areas of special treatment that will apply to SR SSCs, and the working group finds this to be a complete list. The SSC white paper also notes that treatment requirements established through codes and standards yet to be developed will be applied. For these reasons, the working group concludes that the third Outcome Objective, i.e., that the special treatment for the SR category of classification is commensurate with ensuring the SSCs ability to perform their safety function for DBEs and high consequence BDBEs, is reasonable. However, given the lack of design detail at this time, the working group notes that its conclusion does not address the acceptability of any specific NGNP design feature, or SSC performance or treatment. The NRC staff will make determinations as to the acceptability of the specific NGNP design in its review of a future license application which provides the necessary design detail. As discussed above, the working group also notes that the scope of SSCs classified as safety-related appears to be incomplete, which could affect the scope of special treatment attributes addressed for this category.

SUMMARY OF FINDINGS

The working group concludes that the special treatment described for SR SSCs is reasonable. However, a determination that the treatment of those SSCs meets relevant regulatory requirements cannot be completed until the NRC receives a complete license application.

2.3.4 SSC Outcome Objective 4 – Special Treatment of NSRST SSCs

The last SSC white paper outcome objective is:

> The special treatment for the NSRST category is commensurate with ensuring the SSCs ability to perform their safety function of providing significant DID.

The SSC white paper proposes that special treatment requirements for NSR SSCs be commensurate with the requirements needed to enable the SSCs to perform with the capability and reliability requirements during AOOs. Special treatment requirements for NSR SSCs are reduced compared to the special treatment requirements for SR SSCs. The paper states that reduced special treatment requirements are reasonable because the required reliability of NSR SSCs is lower than SR SSCs.

The SSC white paper defines NSRST SSCs as SSCs relied on to perform safety functions to mitigate the consequences of AOOs to comply with the TLRC, or as SSCs relied on to perform safety functions to prevent the frequency of DBEs with consequences greater than the 10 CFR 20 offsite dose limits from increasing into the AOO region.

The SSC white paper proposes that the NGNP PRA be used to establish the required capabilities and reliabilities of NSR SSCs similar to the SR SSCs needed to meet the TLRC. Special treatment requirements for the SR and NSR SSCs will be established in a manner that ensures SSC capability and reliability are consistent with capability and reliability as modeled in the PRA. The special treatment requirements for each NSR SSC are to be based on the specific LBE sequences in which the NSR SSCs are modeled and credited to perform their safety functions in the LBE sequences. That is, special treatments of the NSRST SSCs are used to adjust the ordinates of the AOO LBEs on the F-C chart and are used to also reduce the uncertainties associated with the AOO LBE sequence frequencies and consequences. If the dose consequence ordinate of the AOO sequence and/or the frequency ordinate of the AOO sequence needs to be reduced (so as to make it a DBE sequence), special treatment requirements of one or more NSR SSCs are increased, as needed.

In response to RAI SSC-1, INL stated that the NGNP approach to special treatment is consistent with respect to the criteria of 10 CFR 50.69(d) for deriving special treatment requirements for safety-related and non-safety-related with special treatment SSCs. Consistent with the principles in 10 CFR 50.69, the guiding principle for NGNP is to establish a necessary and sufficient set of special treatment requirements to ensure that each classified SSC has sufficient capability and reliability perform its required safety function. While a different process is used to establish “the safety significance of SSCs”, INL claims that the principles are the same.

WORKING GROUP ASSESSMENT

In RAI SSC-13, the working group noted that the white paper does not clearly state that SSCs described by this section (i.e., NSRST SSCs) will meet regulatory requirements, such as

10 CFR 50.55a(a)(1), which requires that SSCs be "…designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed." The working group requested clarification of NGNP Project's intent for these SSCs in RAI SSC-13.

In their response to RAI SSC-13, INL stated that the NGNP Project expects to conform to future code requirements developed for HTGR plants, which would include HTGR codes developed and incorporated into NRC's regulations such as 10 CFR 50.55a. Code requirements associated with design, fabrication, erection, inspection, testing, operation, and maintenance would be applicable to those SSCs determined to require special treatment to the extent necessary to provide reasonable assurance that such SSCs, as determined through a plant-specific PRA, will perform their intended safety function with sufficient capability and reliability to meet the TLRC. The working group finds this to be adequate clarification.

The working group has identified the following unresolved issues with the approach for special treatment of NSR SSCs.

1. The SSC white paper indicates that special treatment will be adjusted as necessary (presumably during plant operation) to maintain reliability assumptions in the PRA. This will involve a performance monitoring program which was not described in the SSC white paper. The working group notes however, that "operational performance monitoring" is an area of special treatment that will be provided to NSR SSCs. The concern with this feature of the approach is that the relationship between level of a particular type of treatment (e.g., QA, or maintenance) and reliability parameters assumed in the PRA is not well defined. The staff recognized this issue in its preparation for review of large passive light water reactor applications, and accordingly neither the Reliability Assurance Program nor the program for RTNSS purports to directly enforce the assumptions in the PRA.

2. Table 1 of the SSC white paper suggests that special treatment requirements for design reliability, i.e., independence, redundancy and diversity, do not apply to SSCs categorized as NSRST. The staff's position is that NSR SSCs that perform important safety functions should be highly reliable, which includes reliability in design. The working group considers a graded approach to the required level of design reliability to be reasonable. However, eliminating this element of special treatment is, in the working group's view, inconsistent with the NRC's philosophy of defense-in-depth.

3. The NGNP approach does not identify a special treatment program for maintaining availability of NSRST SSCs during plant operation. Technical Specifications are identified as the means of assuring adequate availability of SR SSCs. The working group considers availability to be just as important as reliability and capability for assuring the TLRC are met. Large passive LWR plants develop and implement an Availability Controls Manual that governs availability of important NSR SSCs. Such an approach should also be considered by NGNP.

4. The definition of NSRST SSCs addresses only providing defense-in-depth in terms of controlling the frequency of an accident, i.e., preventing DBEs from increasing in frequency into the AOO region. The definition does not address any role in mitigation of accident consequences. Accident mitigation is an important function which requires defense-in-depth. NRC has set expectations for RTNSS SSCs to provide a high degree of assurance that there is adequate DID for passive LWR designs, so the working group

believes similar expectations addressing both accident frequency and consequences are appropriate for NGNP. An NSRST function to mitigate accidents should be explicitly included in the definition of those SSCs.

5. Table 1 of the SSC white paper lists 15 different special treatment attributes which may be applicable to NSRST SSCs. Therefore, there are over 220 different combinations of attributes which could apply to a single SSC; 100 SSCs could have over 22,000 different combinations. The large number of SSC and attribute combinations, even for a modest number of NSRST SSCs, creates a considerable configuration control challenge, and so introduces a significant possibility that SSCs may be found to be out of compliance with one or more attributes during operation. Furthermore, the level of tracking of special treatment attributes is also unclear from the SSC white paper. For example, a valve can consist of dozens of individual parts. In the existing regulations, all parts of a safety-related valve would be expected to meet all relevant special treatment requirements. Even so, current licensees have occasionally had problems ensuring that those requirements are met, even for a classification and treatment scheme which is less complex than proposed by the SSC white paper.

In addition, the working group believes that use of the NSRST classification introduces additional complexity in license processes and activities. The NSRST definition replaces the existing safety-related definition given in the regulations, at least in part (i.e., SSCs mitigating AOOs). Therefore, it appears to the working group that NGNP may be required to apply for an exemption in order for NRC to approve incorporating this proposal into a future license. However, the SSC white paper does not describe how such an exemption will be justified, and, as described more fully below, the working group does not have sufficient information about the design or any possible exemption application to make a preliminary assessment as to whether this approach is reasonable or would be acceptable.

Requirements for exemptions for combined license or design certification applications are discussed in 10 CFR 52.7, which references the requirements of 10 CFR 50.12, which is also the regulation applicable to a construction permit or operating license application submitted in accordance under the requirements of 10 CFR 50. This regulation (10 CFR 50.12(a)(2)) states that:

> …the Commission will not consider granting an exemption unless special circumstances are present. Special circumstances are present whenever--
>
> (i) Application of the regulation in the particular circumstances conflicts with other rules or requirements of the Commission; or
>
> (ii) Application of the regulation in the particular circumstances would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule; or
>
> (iii) Compliance would result in undue hardship or other costs that are significantly in excess of those contemplated when the regulation was adopted, or that are significantly in excess of those incurred by others similarly situated; or
>
> (iv) The exemption would result in benefit to the public health and safety that compensates for any decrease in safety that may result from the grant of the exemption; or

(v) The exemption would provide only temporary relief from the applicable regulation and the licensee or applicant has made good faith efforts to comply with the regulation; or

(vi) There is present any other material circumstance not considered when the regulation was adopted for which it would be in the public interest to grant an exemption. If such condition is relied on exclusively for satisfying paragraph (a) (2) of this section, the exemption may not be granted until the Executive Director for Operations has consulted with the Commission.

Based on information currently available, the working group does not believe at this time that criteria (i), (iii), (iv), or (v) could be used to justify the necessary exemption.

In the view of the working group, criterion (i) is unlikely to apply, unless the future applicant can clearly show conflict with other regulatory requirements. Given that the term “safety-related” is found throughout the current regulations, it seems more likely to the working group that use of the NSRST classification will create such conflicts than using the existing terminology.

The SSC white paper does not describe why use of the existing safety-related classification would result in hardships or costs necessary to justify use of Criterion (iii). The working group expects that there are some additional costs and burdens associated with safety-related components. Given that it is expected that the NGNP prototype will be a simpler facility than existing reactors, with fewer SSCs needed for mitigating transients and accidents, it is believed by the working group to be unlikely that these costs or burdens will be outside this expected scope, or that a comparison to other reactor types will demonstrate significantly higher costs. However, this preliminary view could possibly change when additional details regarding the proposed NGNP design are provided to the NRC.

Application of criterion (iv) requires demonstration of a public health benefit. The working group believes at this time that it is unlikely that this criterion can be applied. Typically, AOOs are not expected to have offsite radiological consequences. Therefore, it is not practical to expect that reducing special treatment requirements for SSCs mitigating such events will demonstrate significantly improved public health and safety.

Criterion (v) does not appear to the working group to be relevant to NGNP. Given the well-established nature of the term “safety-related” in the regulations, it is not apparent to the working group how the temporary relief clause could be applied. Further, the SSC white paper proposes an alternative to existing regulations, which is unlike describing how the good faith clause would apply.

Based on the discussion above, it is the preliminary view of the working group that 10 CFR 50.12(2)(ii) and 10 CFR 50.12(2)(vi) are the only criteria which may possibly be used to justify the necessary exemption.

In order to apply criterion (ii), a future applicant will need to demonstrate that use of the NSRST classification is not necessary to meet the underlying purpose of any rule which currently uses the term “safety-related.” Given that this term appears extensively within 10 CFR 50, which largely defines the technical requirements for applications made both within the scope of that regulation and for applications submitted under the provisions of 10 CFR 52, the scope of such an exemption will be extensive.

The proposed use of the NSRST classification increases the scope of review for a prospective license application, and introduces additional regulatory uncertainty. The working group notes that there were considerable challenges associated with development of 10 CFR 50.69, which is a rule intended to provide alternative risk-informed classification and special treatment requirements, and was informed by many years operating and licensing experience with over 100 operating light water reactors. There is far less relevant experience with HTGRs, so it is reasonable to anticipate there could be additional uncertainty associated with the NGNP NSRST classification. It is also noted that, as of the date of this assessment, no licensees have implemented 10 CFR 50.69.

Criterion (vi) addresses circumstances not considered when regulations were adopted if it can be demonstrated that the exemption is in the public interest. While many regulations are written in a technology-neutral manner, there are also a number of regulations which are written from a perspective of light water reactor licensing and operation. Therefore, it is possible that an applicant may be able to show that the safety of an advanced reactor technology, such as the NGNP HTGR, can be demonstrated by some set of alternative requirements authorized by an exemption. However, criterion (vi) requires Commission consultation before granting an exemption under that clause, which also increases the scope and complexity of the staff's regulatory review, similar to the challenges presented by use of criterion (ii).

Another regulation which is relevant to the proposed NSRST classification is 10 CFR 21, "Reporting of Defects and Noncompliances." The purpose of this regulation is to require entities which construct, own, operate, or supply components to a nuclear power plant to immediately inform the NRC of defects in the facilities " which could create a substantial safety hazard…" The regulations define attributes of "basic components" which are subject to these reporting requirements. For currently operating reactors, components which mitigate AOOs are considered to be safety-related, and clearly fall within the scope of 10 CFR 21 requirements, so it seems reasonable to the working group to expect that NGNP SSCs mitigating AOOs would be subject to the same requirements. However, the SSC white paper does not address whether NSRST SSCs will be considered basic components or how it is anticipated the requirements of 10 CFR 21 will be applied to NSRST SSCs.

The working group does not expect that the NRC can endorse the NSRST classification until a better understanding of how a future applicant proposes to incorporate the classification by exemption, including the full scope of affected regulations, is provided. An NGNP license applicant will also need to address how other regulatory requirements pertinent to safety-related SSCs, such as 10 CFR 21, will be applied to NSRST SSCs. Given the apparent similarity of NSRST to RTNSS, and that apparently an exemption will be required for its implementation, this topic is considered to be a Commission policy issue.

SUMMARY OF FINDINGS

The working group believes that Outcome Objective 4 cannot be met at this time, in light of these unresolved issues.

- The ability to adjust special treatment and reflect those changes in the PRA has not been established.
- NSRST SSCs should be designed in a highly reliable manner in order to ensure defense-in-depth.
- The means to maintain availability of NSRST SSCs have not been described.

- NSRST should provide enhance defense-in-depth for mitigation of accidents.
- The proposed NSRST classification and treatment scheme appears to be unmanageably complex.
- It is unclear how the NSRST classification can be implemented using an exemption from regulatory requirements.
- The applicability of 10 CFR 21 and other regulatory requirements has not been addressed.

3.0 SUMMARY

This section provides a summary of the working group's key findings. Readers are referred to the text above for the basis of these findings, along with other observations which may be relevant to future NGNP licensing.

The working group has identified two cross-cutting issues which substantially affect many of the findings described in this preliminary assessment. First, there is often insufficient design detail available to interpret or understand how the proposed framework will be implemented. Second, the working group believes that the proposed approach should be strengthened by increased use of deterministic elements. The assessment above discusses how conservative deterministic selection of bounding events can clearly demonstrate compliance with regulatory requirements, and improve defense-in-depth by assuring plant equipment is capable of mitigating a wide range of events.

For licensing basis event selection, the principal working group findings are summarized as follows:

- The approach to the categorization of LBEs is generally reasonable, though the working group believes that deterministic elements should have a stronger role. The NGNP license applicant and NRC staff will need to agree upon the use of deterministic engineering judgment, complemented by NGNP design specific PRA, to deterministically select LBEs in the event categories, consistent with the NGNP design and safety characteristics and Commission policy decisions.
- The NGNP applicant and NRC staff will need to agree upon the event categories and the events needed to demonstrate NGNP conformance with 10 CFR 52.79 and the defense-in-depth capability to retain fission products.
- The limits on the event frequency ranges that define the AOO, DBE and BDBE categories are reasonable with some modifications.
- The applicable dose limits for the event sequences and the rules for the mechanistic source term calculation for AOOs should be revised to ensure a conservative result.
- The cutoff frequencies should be revised in order for NGNP to clearly demonstrate conformance with NRC safety goals.
- Whether PRA initiating events and event sequences below 1E-8/reactor-year can be dropped from consideration for establishing emergency planning requirements is a Commission policy decision.
- The proposed approach to events, failures, and natural phenomena is generally reasonable. However, the NRC requirements and expectations arising from the

Fukushima Dai-Ichi earthquake and tsunami may result in additional external events (e.g., natural phenomena) and the associated event sequences to be considered for NGNP licensing.

- The approach to the development of the NGNP DBAs is reasonable with some modification and the use of conservative calculation for the DBA mechanistic source term is appropriate.

For defense-in-depth, the working group highlights the following issues:

- Risk metrics should be established for NGNP so the staff can deliberate further on the adequacy of the DID approach.
- The NGNP Project's reliance on PRA is not commensurate with current state of PRA quality and completeness.
- DID is a topic potentially requiring Commission deliberation; moreover, DID is closely linked to other potential technical/policy issues (e.g., mechanistic source term, containment functional performance, and emergency planning).
- It is not clear on how exactly the uncertainties are accounted for in the development of plant capability DID, especially when the NGNP design is not clearly defined.

For SSC classification and treatment, the working group has identified these key issues:

- Key fission product barriers should be safety-related.
- SSCs which prevent release of radioactivity during AOOs should be safety-related.
- The proposed approach does not address the role of regulatory treatment of non-safety systems (RTNSS) in defense-in-depth.
- Assessment of SSC capability and reliability should be based on more than the frequency and consequences of events mitigated.
- The proposed classification of NSRST does not appear to be adequately justified, and is expected to be difficult to implement.

Based on review of the proposed risk-informed, performance-based licensing approach, the working group believes that the approach proposed by the white papers discussed above may not be consistent with the intent of Option 2 of the Licensing Strategy Report. The working group has identified a number of issues which challenge the effective implementation of a risk-informed, performance-based licensing framework for NGNP, which may increase uncertainty for a future license application, increasing the level of NRC effort and time required to complete a review. Resolution of these issues during pre-application interactions with a prospective designer and/or licensee may reduce regulatory uncertainty for a subsequent licensing review. The working group reiterates that these findings and observations are preliminary, given the lack of detailed design information available. The NRC staff will be in a better position to judge the adequacy of the proposed risk-informed, performance-based framework by examining its implementation as more design information is provided.

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Appendix A

NGNP Licensing Basis Event Selection White Paper Outcome Objectives

These outcome objectives are as stated in the September 16, 2010, submittal.

1. The structured process for selecting LBEs is an acceptable approach for defining the LBEs.

NGNP Approach: An acceptable approach starts with a deterministically selected initial event list. It then includes a design-specific PRA with the following elements: an engineering analysis of the plant response to each initiating event using verified computer models, deterministic success criteria, and conservative deterministic safety analyses of DBAs in Chapter 15 of the license application. Both the deterministic and probabilistic analysis will be supported by a comprehensive and systematic search for initiating events, including internal events and internal and external plant hazards that could occur during all operating and shutdown modes, and covering the sources of radioactive material.

2. LBEs cover a comprehensive spectrum of events from normal operation to rare, off-normal events.

There are three categories of LBEs:

a. 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.

b. 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.

c. 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.

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 multimodule plant design meets the NRC safety goals.

NGNP Approach: The three categories of LBEs and their purposes adhere to the existing NRC regulations and policy. The LBEs include AOOs, DBEs, and BDBEs used in NRC regulatory policy and guidance. DBEs, as well as AOOs and BDBEs, are selected through the use of the PRA and are based on a realistic response of the entire plant. This is the necessary foundation for understanding the safety functions and the SSCs available to perform them. This leads to the safety classification of SSCs, which is the subject of another paper. Once the SSC safety classification is known, the deterministically selected initial event list is risk-informed by DBAs that are derived from the DBEs by demonstrating success paths for the DBAs relying solely on their response of safety-related SSCs, as in the conventional regulatory practice.

3. The frequencies of LBEs are expressed in units of events per plant-year where a plant is defined as a collection of reactor modules having certain shared systems. The limits on the frequency ranges for the LBE categories are as follows:

a. AOOs – event sequences with mean frequencies greater than 10-2 per plant-year

b. DBEs – event sequences with mean frequencies less than 10-2 per plant-year and greater than 10-4 per plant-year

c. BDBEs - event sequences with mean frequencies less than 10-4 per plant-year and greater than 5 x10-7 per plant-year.

NGNP Approach: For AOOs, the NGNP Project proposes a lower frequency limit of 10-2 per plant year.

For DBEs, NGNP Project proposes a lower frequency range for event sequences of 10-4 per plant-year, which meets the NRC safety goals and is consistent with LWR regulatory practice.

For BDBEs, NGNP Project proposes a lower limit of 5 × 10-7 per plant-year.

To account for multimodule concepts, the NGNP Project proposes that the frequency be stated on a per plant-year basis. For example, the frequency for a 10-4 per plant-year event impacting only one of an eight reactor module facility is 1.25 × 10-5 per plant-year. For events impacting more than one and up to all eight reactor modules, such as earthquakes, the frequency is 10-4 per plant-year and the consequences will take into account all eight reactor modules. By setting the lower bound of the DBE region at 10-4 per plant-year, NGNP is committing to design for all events, whether impacting one reactor module or all the reactor modules.

4. Acceptable limits on the event sequence consequences and the analysis basis for the LBE categories are as follows:

a. AOOs – 10 CFR Part 20: 100 mrem TEDE mechanistically modeled and realistically calculated at the EAB

b. DBEs – 10 CFR 50.34: 25 rem TEDE mechanistically modeled and conservatively calculated at the EAB

c. BDBEs – NRC safety goal QHOs mechanistically and realistically calculated at 1 mile (1.6 km) and 10 miles (16 km) from the plant.

NGNP Approach: The acceptable public consequences have been derived from the existing regulations and policy in Section 2. In summary, the limits in 10 CFR Part 20 are applied to AOOs and the limits in 10 CFR 50.34 are applied to the DBEs and the DBAs. The safety goal QHOs are applied to all the LBEs in a cumulative manner. The analyses bases follow the conventional practice for each of the LBE categories and respective TLRC.

5. The frequency below which events are not selected as LBEs is 5 × 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.

> NGNP Approach: BDBEs will meet the NRC safety goals at the prescribed distances from the plant.
>
> The NGNP project proposes 5 × 10-7 per plant-year, since lower frequency events by definition meet the NRC safety goal QHO for acute individual risk of fatality.

6. The kinds of events, failures, and natural phenomena that are evaluated include:

> a. Multiple, dependent, and common cause failures to the extent that these contribute to LBE frequencies
>
> b. Events affecting more than one reactor module
>
> c. Internal events (including transients and accidents) 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.
>
> NGNP Approach: The PRA supporting the application will be a full scope (including all operating modes) evaluation. A future NGNP white paper will discuss this topic in greater detail.

7. The DBAs for Chapter 15, "Accident Analysis," of the license application are derived from the DBEs by assuming that only SSCs classified as safety-related are available to mitigate the consequences. The public consequences of DBAs are based on mechanistic source terms and are conservatively calculated. The upper bound consequence of each DBA must meet the 10 CFR 50.34 consequence limit at the EAB.

> NGNP Approach: The DBAs will be derived from the DBEs by considering only the response of SSCs classified as safety-related. The consequences of DBAs will be based on mechanistic source terms and will be conservatively calculated. The upper bound consequence of each DBA will meet the 10 CFR 50.34 consequence limit at the EAB.

8. Uncertainty distributions are evaluated for the mean 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 on the LBE frequency straddles two or more regions, 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 for the DBE and DBA consequences must meet the 10 CFR 50.34 dose limit at the EAB.

NGNP Approach: Uncertainty distributions will be evaluated for the mean frequency for each LBE. The mean frequency will be used to determine whether the event sequence family is an AOO, DBE, or BDBE. If the upper or lower bound on the LBE frequency straddles two regions, the LBE will be compared against the consequence criteria for each region.

Appendix B

NGNP Defense-in-Depth White Paper Outcome Objectives

These outcome objectives are as stated in the December 9, 2009, submittal.

1. The definition of defense-in-depth presented in Section 3 of this paper, which recognizes three elements of a defense-in-depth approach: Plant Capability Defense-in-Depth, Programmatic Defense-in-Depth, and Risk-Informed Evaluation of defense-in-depth, is consistent with available definitions summarized in the regulatory foundation and is appropriate for the NGNP license application.

2. The Plant Capability Defense-in-Depth element, which includes multiple independent and diverse barriers to radionuclide transport, the use of inherent features and passive and active SSCs to perform the required safety functions, and conservative design strategies, is appropriate for the license application.

3. The Programmatic Defense-in-Depth element represents an acceptable approach to incorporation of defense-in-depth principles into the definition of programs that will provide assurance that the plant capabilities to assure safety and defense-in-depth will have sufficient reliability and be maintained throughout the lifetime of the plant and that uncertainties are adequately addressed by compensatory actions.

4. The Risk-Informed Evaluation of defense-in-depth element provides an acceptable balance of deterministic and probabilistic assessments and evaluation criteria. Further, this element includes an acceptable event sequence framework for the definition of accident prevention and mitigation, and for the evaluation of the roles of design features and SSCs responsible for prevention and mitigation for demonstrating the safety case. Finally, the balanced use of deterministic and probabilistic evaluations provides a logical process to establish the adequacy and sufficiency of defense-in-depth for the NGNP Project.

5. When the approach described in this paper is applied in the NGNP license application, the NRC will have sufficient information on which to judge the adequacy of the defense-in-depth provisions. This information will include:

a. A definition of defense-in-depth that is appropriate for the NGNP Project.

b. The roles of each barrier to radioactive material retention for each significant inventory of radionuclides in providing the plant capabilities for defense-in-depth.

c. How the reliability, capability, and independence of each barrier are defined and evaluated in terms of their plant capabilities for defense-in-depth.

d. How the safety functions are defined and how they support the integrity of each barrier in providing the plant capabilities for defense-in-depth.

e. The roles of diverse combinations of inherent and passive design features and SSCs that are used as well as active engineered systems to perform the safety functions as part of the plant capabilities for defense-in-depth.

f. How the reliability, capability, and independence of each SSC providing a safety function is defined and evaluated as it relates to the plant capabilities for defense-in-depth.

g. How the principles of design margins, redundancy, diversity, and independence have been applied in providing the plant capabilities for defense-in-depth.

h. An appropriate definition of accident prevention and mitigation and a means to evaluate the impact of the defense-in-depth strategies on maintaining acceptable risk levels.

i. The roles and effectiveness of specific barriers and SSCs in the prevention and mitigation of accidents.

j. The role design safety margins reflected in the applied codes and standards play in providing a robust design with defense-in-depth.

k. How compensating measures and other aspects of Programmatic Defense-in-Depth are applied to address uncertainties.

l. How a set of deterministic principles derived from the regulatory foundation is applied in the risk-informed evaluation of the adequacy and sufficiency of defense-in-depth for the NGNP Project.

m. How the elements of the safety design approach are used to evaluate plant design features in an integrated manner as part of an overall risk management approach in which risk analysis is used to improve operational and engineering decisions broadly by identifying and taking advantage of opportunities to reduce risk.

Appendix C

NGNP Structures, Systems, and Component Safety Classification and Treatment
White Paper Outcome Objectives

These outcome objectives are as stated in the September 21, 2010, submittal.

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

2. The NGNP risk-informed safety classification categories and the bases for SSC classification within each category are acceptable

3. The special treatment for the SR category of classification is commensurate with ensuring the SSCs ability to perform their safety function for DBEs and high consequence BDBEs

4. The special treatment for the NSRST category is commensurate with ensuring the SSCs ability to perform their safety function of providing significant DID.