OFFICE OF NEW REACTORS

SUMMARY FEEDBACK ON FOUR KEY LICENSING ISSUES

NEXT GENERATION NUCLEAR PLANT
PROJECT 0748

INTRODUCTION

The U.S. Department of Energy (DOE) and its Idaho National Laboratory (INL) (hereafter referred to collectively as DOE/INL) established the Next Generation Nuclear Plant (NGNP) Project as required by Congress in Subtitle C of Title VI of the Energy Policy Act of 2005 (EPAct). The mission of the NGNP Project is to develop, license, build, and operate a prototype high-temperature gas-cooled reactor (HTGR) plant that generates high temperature process heat for use in hydrogen production and other energy intensive industries while also generating electric power. To fulfill this mission, DOE/INL is considering a modular HTGR with either a prismatic block or pebble bed core.

As stipulated by the EPAct, DOE/INL and the U.S. Nuclear Regulatory Commission (NRC) have been engaged in prelicensing interactions on technical and policy issues that could affect the design and licensing of the NGNP prototype. Such early interactions are encouraged by the Commission's policy statement on advanced reactors.[1]

As outlined by the NRC in a letter to DOE dated February 15, 2012, the NRC staff has since focused its NGNP interactions with DOE/INL on the further assessment of technical and policy issues in key areas previously highlighted in the NGNP Licensing Strategy Report that NRC and DOE jointly issued to Congress in 2008.[2] In the current document, the NRC staff discusses these issues under the following four headings:

(1) Licensing basis event selection
(2) Source terms
(3) Functional containment performance
(4) Emergency preparedness

DOE/INL has engaged the NRC staff on its proposed approaches to such issues primarily through a series of white paper submittals. In February 2012, the NRC provided its preliminary feedback to DOE/INL in the form of two initial assessment reports (ML120240671).[3] Subsequent interactions have largely focused on addressing issues and follow up items identified in those initial assessment reports. DOE/INL brought further focus to these interactions in its letter to NRC dated July 6, 2012 (ML121910310).

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1 "Policy Statement on the Regulation of Advanced Reactors," Volume 73 of the *Federal Register*, page 60612 (73 FR 60612); October 14, 2008

2 "Next Generation Nuclear Plant Licensing Strategy – A Report to Congress," August 2008, (NRC Agencywide Documents Access and Management System (ADAMS) Accession No. ML082290017)

3 Note that this and subsequent references to ADAMS omit "ADAMS Accession No." for brevity.

The remainder of this NRC staff document summarizes and consolidates the staff's views in terms of the July 6th letter's requests for feedback under each of the four key issue headings. More detailed NRC staff comments on related issues are provided in the following updated white paper assessment report, which is being issued concurrently with this document: "Assessment of White Paper Submittals on Fuel Qualification and Mechanistic Source Terms," Revision 1 (ML13220A234). The issue discussions that follow refer to that NRC assessment report on fuel qualification (FQ) and mechanistic source terms (MST) as the "FQ-MST assessment report" and to the respective DOE/INL white paper submittals as the "FQ white paper" (ML102040261) and the "MST white paper" (ML102040260). The discussions also refer to DOE/INL's proposed approaches to risk-informed, performance-based NGNP licensing that are described in the three white paper submittals on defense in depth (ML093480191), licensing basis event selection (ML102630246), and safety classification of structures, systems, and components (ML102660144).

As mutually agreed with the NRC early in the assessment process, DOE/INL did not submit revisions to the white papers during the assessment process; however, DOE/INL did indicate that any future NGNP prelicensing or licensing submittals related to topics in the white papers would incorporate revisions and clarifications derived from the assessment interactions. Until such future submittals become available, the NRC staff recommends that the submitted white papers be considered in conjunction with the comments, clarifications, additional information, and effective/suggested revisions presented herein and in the staff's FQ-MST assessment report.

RESPONSES TO SPECIFIC REQUESTS FOR NRC FEEDBACK

The responses provided here reflect the NRC staff's evolving interest in pursuing risk informed, performance-based approaches for licensing advanced reactors. In an August 2012 report to Congress on advanced reactor licensing, the NRC staff indicated its initiative to streamline its review of new reactor licensing applications.[4] In that report, the NRC discussed its approach to licensing light-water small modular reactor (SMR) designs and non-light-water reactor (non-LWR) advanced reactor designs. The approach includes: "(1) use a more risk-informed and integrated review framework for staff preapplication and application review activities pertaining to iPWR design applications; and, (2) develop, over the longer term, a new risk-informed, performance-based regulatory structure for licensing non-LWR advanced reactor designs (e.g., high-temperature, gas-cooled reactors (HTGRs) and liquid-metal reactors (LMRs))."

The NRC staff statements that follow, as with those in the staff's FQ-MST assessment report, do not provide a final regulatory decision on any aspect of the NGNP design concepts because such conclusions would be provided in the NRC staff's safety evaluation of a future license or design certification application. Although these views represent the engineering and licensing judgment of the NRC staff, they are based on generic modular HTGR design concepts rather than a specific design and were not developed in the context of a docketed license application. Therefore, these NRC staff statements are advisory. Moreover, since many of the technical and policy issues cannot be addressed or resolved until more specific and detailed information about the NGNP design is available and further policy direction is provided in some areas, the staff

[4] *Report to Congress: Advanced Reactor Licensing*, August 2012 (ML12153A014)

views presented here are subject to change and to future consideration by the Commission.[5] The views presented here are based on consideration of previous NRC staff recommendations and Commission policy precedence. The staff identifies certain issues as potential Commission policy issues, meaning that the staff may ask the NRC Commissioners for policy guidance in resolving such issues.

Lastly, although DOE/INL has framed some of its feedback requests using words like "accept," "acceptable," and "endorse," it bears noting that such words have legal/regulatory connotations that would not be appropriate in this context. The staff instead addresses such requests in terms of whether DOE/INL's proposed approaches to the respective issues are "reasonable."

1. Licensing Basis Event Selection

History of Pertinent NRC Staff and Commission Positions

DOE/INL's white paper on licensing basis event (LBE) selection includes a discussion of NRC requirements, policies, and guidance identified as relevant to the selection and treatment of NGNP licensing basis events. That discussion appropriately identifies the limited LBE-related guidance that has been developed or proposed specifically for modular HTGRs and other non-LWR designs. However, DOE/INL's discussion also includes some less relevant and potentially confusing assertions in reference to the core damage frequency (CDF) goal that was established by the Commission in the staff requirements memorandum (SRM) dated June 26, 1990, to SECY-90-016, "Evolutionary LWR Certification Issues and their Relationships to Current Regulatory Requirements."

As a point of clarification, the staff notes that a CDF below 10^{-4} per reactor-year can only be achieved if each accident that contributes to the total CDF has a frequency well below 10^{-4} per reactor-year. This clarification is consistent with related guidance on design basis accidents for LWRs, including the guidance on initiating event frequencies that the Commission later provided in the SRM dated July 1, 2004, to SECY-04-0037, "Issues Related to Proposed Rulemaking to Risk-Inform Requirements Related to Large Break Loss-of-Coolant Accident (LOCA) Break Size and Plans for Rulemaking on LOCA with Coincident Loss-of-Offsite Power."

The LBE white paper correctly notes the limited applicability of such LWR-specific guidance to modular HTGRs. Accordingly, the staff's assessment of any proposed approaches to LBE selection for modular HTGRs would build mainly upon the more clearly relevant NRC policy and guidance considerations noted in the paragraphs that follow.

In SECY-93-092, "Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and PIUS) and CANDU-3 Designs and Their Relationship to Current Regulatory Requirements," dated April 8, 1993, the NRC staff provided positions for the Commissioners to consider in providing policy guidance on a risk-informed licensing structure that would be acceptable. Included was a discussion of accident analysis and licensing basis event evaluation. Note that SECY-93-092 was based, in part, on the NRC staff's preapplication review efforts, as documented in NUREG-1338, "Draft Preapplication Safety Evaluation Report for the Modular

[5] The term "Commission," as used in this document, refers to the five appointed NRC Commissioners, whereas the term "staff" refers to NRC career staff.

High-Temperature Gas-Cooled Reactor [MHTGR]" issued March 1989, for a proposed modular HTGR design and licensing approach very similar to those now proposed for NGNP.

The following statements from SECY-93-092 describe the evaluation approach that the NRC staff proposed for all advanced reactor designs:

- Events and sequences will be selected deterministically and will be supplemented with insights from probabilistic risk assessments of the specific designs.

- Categories of events will be established according to expected frequency of occurrence. One category of events that will be examined is accident sequences of a lower likelihood than traditional light-water reactor (LWR) design-basis accidents. These accident sequences would be analyzed without applying the conservatisms used for design-basis accidents. Events within a category equivalent to the current design-basis accident category will require conservative analyses, as is presently done for LWRs.

- Consequence acceptance limits for core damage and onsite/offsite releases will be established for each category to be consistent with Commission policy guidance.

- Methodologies and evaluation assumptions will be developed for analyzing each category of events consistent with existing LWR practices.

- Source terms will be determined as approved by the Commission in Section B [SECY-93-092, Section B "Mechanistic Source Term"].

- A set of events will be selected deterministically to assess the safety margins of the proposed designs, to determine scenarios to mechanistically determine a source term, and to identify a containment challenge scenario.

- External events will be chosen deterministically on a basis consistent with that used for LWRs.

- Evaluations of multi-module reactor designs will be considered as to whether specific events apply to some or all reactors on site for the given scenario for all operations permitted by proposed operating practices.

In the staff requirements memorandum (SRM) dated July 30, 1993, to SECY-93-092, the Commission approved these evaluation principles for advanced reactors.[6] The NRC staff then reviewed these principles and refined them in SECY-03-0047, "Policy Issues Related to Licensing Non-Light-Water Reactor Designs," dated March 28, 2003.

In SECY-03-0047, the NRC staff proposed to place greater emphasis on the use of risk information by allowing the use of a probabilistic approach for identifying events to be considered in an applicant's design bases, provided that plant and fuel performance are sufficiently understood and deterministic engineering judgment is used to bound uncertainties in

[6] As noted subsequently in this document, the Commission's approval regarding MHTGR containment challenge scenarios stated that the staff should also consider the potential for "chimney effect" air-ingress events with graphite oxidation.

the applicant's analysis. Specifically, the staff recommended in SECY-03-0047 that the Commission should take the following three actions to define the extent to which a probabilistic approach can be used to establish the licensing basis:

(1) Modify the Commission's guidance, as described in the SRM of July 30, 1993, to SECY-93-092, to put greater emphasis on the use of risk information by allowing the use of a probabilistic approach in the identification of events to be considered in the design, provided there is sufficient understanding of plant and fuel performance and deterministic engineering judgment is used to bound uncertainties.

(2) Allow a probabilistic approach for the safety classification of structures, systems, and components.

(3) Replace the single failure criterion with a probabilistic (reliability) criterion.

The Commission then approved these recommendations without revision in the SRM to SECY-03-0047. Note that these approved recommendations are consistent with a risk-informed approach in that they extend the use of probabilistic risk assessment (PRA) into forming part of the basis for licensing and thereby place greater emphasis on PRA quality, completeness, and documentation. Additionally, the staff provided updates to the Commission on the development of a regulatory structure for new plant licensing in SECY-04-0157, "Status of Staff's Proposed Regulatory Structure for New Plant Licensing and Potentially New Policy Issues," dated August 30, 2004, and in SECY-05-0006, "Second Status Paper on the Staff's Proposed Regulatory Structure for New Plant Licensing and Update on Policy Issues Related to New Plant Licensing," dated January 7, 2005.

In December 2007, the NRC staff published NUREG-1860, "Feasibility Study for a Risk-Informed and Performance-Based Regulatory Structure for Future Plant Licensing," Volume 1, "Main Report," and Volume 2, "Appendices A through L," which explored the feasibility of developing a risk-informed and performance-based regulatory structure for the licensing of future nuclear power plants. As such, NUREG-1860 documents a framework that provides an approach, scope, and criteria that could be used as a guide to develop a set of new regulations to serve as an alternative to current regulations for licensing future nuclear power plants.

In August 2008, the NRC and DOE jointly issued to Congress the NGNP Licensing Strategy Report. The strategy report describes four options for adapting existing NRC regulatory requirements. These options range 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 the NRC endorsed Option 2, a risk-informed and performance-based approach that uses deterministic engineering judgment and analysis, complemented by NGNP design-specific PRA information, to establish the licensing basis, including the selection of LBEs and licensing technical requirements. The quality and completeness of the PRA should be commensurate with the reliance on the PRA in establishing the licensing basis.

Current NRC Policy Development Activities related to Licensing Basis Event Selection for New and Advanced Reactors

On July 12, 2011, the NRC published the report, "Recommendations for Enhancing Reactor Safety in the 21st Century – The Near-Term Task Force [NTTF] Review of Insights from the Fukushima Dai-ichi Accident" as an enclosure to SECY-11-0093, "Near-Term Report and

Recommendations for Agency Actions Following the Events in Japan." NTTF Recommendation 1, the first of the report's twelve overarching recommendations, is to establish a logical, systematic, and coherent regulatory framework for adequate protection that appropriately balances defense-in-depth and risk considerations. In an August 19, 2011, SRM for SECY-11-0093, the Commission set forth its direction to the staff with respect to the recommendations in the NTTF report. For Recommendation 1, the Commission stated:

> Recommendation 1 should be pursued independent of any activities associated with the review of the other Task Force recommendations. Therefore, the staff should provide the Commission with a separate notation vote paper within 18 months of the issuance of this SRM. This notation vote paper should provide options and a staff recommendation to disposition this Task Force recommendation.

On December 6, 2013, the staff issued SECY-13-0132, "U.S. Nuclear Regulatory Commission Staff Recommendation for Disposition of Recommendation 1 of the Near Term Task Force Report." The purpose of this notation vote paper was to seek Commission approval of the staff's recommendations for dispositioning NTTF Recommendation 1. In the paper, the staff recommended the following three potential regulatory improvement activities to disposition NTTF Recommendation 1:

(1) Establish a design-basis extension category of events and requirements and associated internal NRC guidance, policies, and procedures. The design-basis extension category would be applied in a forward-looking and generic basis. The internal NRC guidance would specify how to write future design-basis extension requirements in a consistent, logical, and complete manner, including the need to address "attributes" such as performance goals, treatment requirements, documentation requirements, change processes, and reporting requirements.

(2) Establish Commission expectations for defense in depth through the development of a policy statement that includes: the definition, objectives, and principles of defense in depth; associated implementation guidance containing decision criteria for ensuring adequacy of defense in depth; and conforming guidance to ensure integration of defense in depth with risk.

(3) Clarify the role of voluntary industry initiatives in the NRC regulatory process by specifying when these initiatives may be credited and providing guidance regarding what type and level of licensee documentation and NRC oversight is appropriate for future industry initiatives.

On May 19, 2014, the Commission's SRM for SECY-13-0132 disapproved all of these staff-recommended improvement activities, as written in SECY-13-0132. The SRM also directed the staff to re-evaluate the objectives of Improvement Activities 1 and 2, as appropriate, in the context of the Commission's direction on a long-term Risk Management Regulatory Framework (RMRF), which is described in the paragraphs that follow.

In April 2012, the NRC staff published NUREG-2150, "A Risk Management Regulatory Framework," which describes the results of a task force study on a proposed risk management regulatory approach that could be used to improve consistency among the NRC's various programs. Commissioned by then-NRC Chairman Gregory Jaczko and headed by Commissioner George Apostolakis, the task force's charter was to develop a strategic vision

and options for adopting a more comprehensive, holistic, risk-informed, performance-based regulatory approach for reactors, materials, waste, fuel cycle, and transportation that would continue to ensure the safe and secure use of nuclear material. The proposed risk management regulatory framework builds upon well established practices, such as the NRC's defense-in-depth philosophy and its policies to incorporate risk-informed and performance-based approaches into the agency's regulation and oversight of byproduct, source, and special nuclear materials.

DOE/INL proposes a risk-informed and performance-based licensing approach for the NGNP prototype that is largely consistent with the approach that DOE proposed for the MHTGR in the mid-1980's and that the staff evaluated as described in its draft MHTGR Preapplication Safety Evaluation Report (NUREG-1338), which was initially issued in 1989 and then updated in 1995. These approaches are conceptually similar to those that have been or may be considered for NUREG-1860 and NUREG-2150. A revised or new framework resulting from these other efforts could thus change the current NRC staff positions discussed in this document and the FQ-MST assessment report.

On June 14, 2012, then-NRC Chairman Jaczko issued a tasking memorandum, "Evaluating Options Proposed for a More Holistic Risk-Informed, Performance-Based Regulatory Approach," directing the staff to review NUREG-2150 and provide a paper to the Commission within six months of the staff requirements memorandum on the NTTF Recommendation 1 notation vote paper that would identify options for modifying the regulatory framework and make recommendations, including the potential development of a Commission policy statement.

In response, the staff formed an agency-wide, interoffice working group to develop options and recommendations for the Commission. The working group is currently developing a draft policy statement that would establish Commission expectations across the entire agency regarding a risk management regulatory framework with elements such as those shown in the Figure 1 below. In addition, the working group is developing a plan for addressing the 50 recommendations in NUREG-2150. Some of the recommendations for power reactors, including Generation IV designs such as modular HTGRs, involve developing a risk-informed and performance-based approach to licensing that uses deterministic engineering judgment and analysis, complemented by design-specific PRA information, to establish the licensing basis, including the selection of LBEs and licensing technical requirements. This would include making changes to the licensing-basis event selection process such as expanding the scope of licensing-basis events to include what have traditionally been referred to[7] as "beyond-design-basis events" and developing methods for selecting licensing-basis events that utilize information from a PRA and considerations of defense in depth.

In SRM–SECY-11-0024, "Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews," May 11, 2011 (ADAMS Accession No. ML111320551), the Commission approved the staff's plans for developing, over the longer term, a recommendation for a risk-informed and performance-based regulatory structure for SMRs with advanced designs (e.g., modular HTGRs and liquid-metal fast reactors). However, changes in the environment since 2011 affect the staff's plan discussed in SECY-11-0024 for development of a recommendation, over the longer term, related to a new risk-informed regulatory structure for advanced reactors. Several factors, including DOE decisions regarding the NGNP project, updated industry plans

[7] The term beyond-design-basis is used primarily in informal contexts (e.g., NRC technical reports). It is used sparsely in the Commissions regulations; See 10 CFR 50.44 and 10 CFR 50.150.

and schedules, agency priorities and budgets, and the current Commission-directed activities related to NTTF Recommendation 1 and NUREG-2150, resulted in the need to revise the plans discussed in SECY-11-0024. The staff will not conduct pilot studies, as described in SECY-11-0024, in which a technology-neutral regulatory structure will be considered for SMRs.

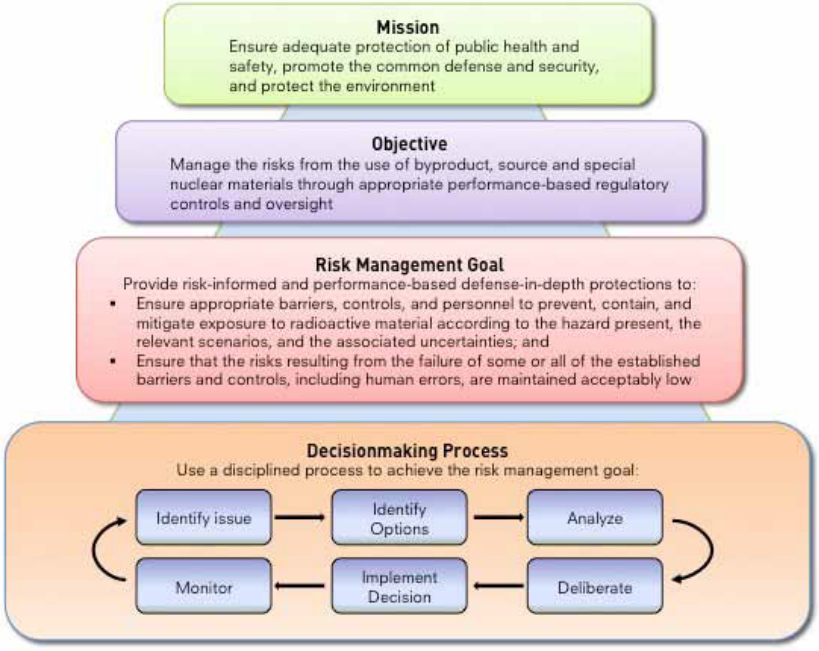

Figure 1 - A proposed Risk Management Regulatory Framework

Responses to DOE/INL Requests Concerning Licensing-Basis Event Selection

When completed, the NRC policy development activities described above will clarify the direction the staff will take in shaping a future approach to licensing-basis event selection for advanced reactors. Therefore, it is premature at this time for the NRC staff to take a position on any of the elements of the approach for licensing-basis event selection proposed by DOE/INL.

The staff will remain cognizant of ongoing agency activities related to NUREG-2150. In addition, the staff will continue to maintain awareness of interagency and external factors that are relevant to the staff's plans, such as the recently established DOE-NRC initiative on general design criteria for advanced reactors. Relevant external factors may also include, for example, initiatives by the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) as well as new and continuing efforts on consensus standards such as the American National Standards Institute (ANSI) / American Nuclear Society (ANS) standard, ANSI/ANS-53.1, "Nuclear Safety Design Process for Modular Helium-Cooled Reactor Plants," and ANSI/ANS-54.1, "Nuclear Safety Criteria and Design Process for Liquid-Sodium-Cooled Nuclear Power Plants."

Consistent with the NRC's "Report to Congress: Advanced Reactor Licensing" and agency budget limitations, the staff intends to progressively increase engagement within the international regulatory community with respect to advanced reactors. As part of this

engagement, the staff intends to consider the merits of international (e.g., International Atomic Energy Agency) standards and guidance.

2. Mechanistic Source Terms

History of Pertinent NRC Staff and Commission Positions

For power reactor combined licenses, 10 CFR 52.79(a)(1)(vi) requires a description and safety assessment of the site, including an evaluation of the major structures, systems, and components (SSCs) that "bear significantly on the acceptability of the site" under the radiological consequence evaluation factors. This assessment should assume a postulated fission product release from the core into the containment with the facility operating at the ultimate power level contemplated. The regulations at 10 CFR 100.21, "Non-Seismic Siting Criteria," require that each applicant for a construction permit or operating license on or after January 10, 1997 (new reactors/advanced reactors), comply with 10 CFR 50.34(a)(1)(ii), which provides similar requirements.

The following site radiological consequence evaluation factors appear in 10 CFR 52.79(a)(1)(vi) and 10 CFR 50.34(a)(1)(ii)(D)

- An individual located at any point on the exclusion area boundary (EAB) for any 2-hour period following the onset of the postulated fission product release would not receive a radiation dose in excess of 25 rem total effective dose equivalent (TEDE).

- An individual located at any point on the outer boundary of the low population zone who is exposed to the radioactive cloud resulting from the postulated fission product release (during the entire period of its passage) would not receive a radiation dose in excess of 25 rem TEDE.

Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," establishes minimum requirements for the design criteria for water-cooled nuclear power plants. General Design Criterion 19, "Control Room," states, for new reactors, that "adequate radiation protection shall be provided to ensure that radiation exposures shall not exceed 0.05 sieverts (5 rem) TEDE as defined in 10 CFR 50.2 for the duration of the accident."

Footnote 6 to 10 CFR 50.34 describes the source term assumed for these postulated events as follows:

> The fission product release assumed for this evaluation should be based upon a major accident, hypothesized for purposes of site analysis or postulated from considerations of possible accidental events. Such 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.

The licensing approach for large LWRs assumes that the major accident used for siting purposes is a severe accident that results in a substantial core melt and large fission product release to containment. In particular, this deterministic source term is used to

evaluate the release mitigation effectiveness of the engineered safeguards systems, including the containment and safety-related filtration and ventilation systems.

The NRC developed NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Chapter 15, "Transient and Accident Analysis," Section 15.0.3, "Design Basis Accident Radiological Consequence Analyses for Advanced Light Water Reactors," issued March 2007, to help the staff in licensing reviews of new large LWRs. Section 15.0.3 of NUREG-0800 states that the guidance on DBA source terms in Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," is acceptable for use at LWRs as it applies to the design. The alternative source term (as it is commonly known) provides guidance on modeling assumptions for fission product release, transport, and mitigation for the accidents evaluated in DBA and siting analyses.

The intent of the postulated fission product release described in 10 CFR 50.34(a)(1)(ii)(D) is to provide a bounding analysis for plant siting purposes in accordance with 10 CFR Part 100, "Reactor Site Criteria." However, the accident described in Footnote 6 in 10 CFR 50.34 is not representative of the wide spectrum of possible events that make up the planning basis of EP; therefore, it is not sufficient by itself for that purpose. In Regulatory Guide 1.183, the NRC staff states that "the NRC staff does not preclude the appropriate use of the insights of the alternative source term in establishing emergency response procedures, such as those associated with emergency dose projections, protective measures, and severe accident management guides." In addition, SECY-97-020, "Results of Evaluation of Emergency Planning for Evolutionary and Advanced Reactors," dated January 27, 1997, states, among other criteria, the following criterion for determining the generic distance for the plume exposure pathway emergency planning zone (EPZ):

> The EPZ should encompass those areas in which projected dose from design-basis accidents could exceed the EPA [U.S. Environmental Protection Agency] PAGs [protective action guidelines].

In SECY-93-092, the NRC staff recommended that source terms for modular HTGRs should be based on a bounding mechanistic analysis that meets certain performance and modeling criteria supported by research and test data. In its SRM to SECY-93-092, the Commission approved the staff's recommendation.

The issue of source terms was revisited in SECY-03-0047 with regard to the following question:

> Under what conditions, if any, should scenario-specific accident source terms be used for licensing decisions regarding containment and site suitability?

SECY-03-0047 includes the NRC staff's recommendation that the Commission should take the following action:

> Retain the Commission's guidance contained in the July 30, 1993, SRM that allows the use of scenario-specific [event-specific] source terms, provided there is sufficient understanding and assurance of plant and fuel performance and deterministic engineering judgment is used to bound uncertainties.

The Commission approved this staff recommendation in its SRM to SECY-03-0047. The approved recommendation allows credit to be given for the unique aspects of plant design (i.e., it is performance based) and further notes the following:

> This approach is consistent with prior Commission and ACRS views. However, this approach is also dependent upon understanding fuel and fission product behavior under a wide range of scenarios and on ensuring [that] fuel and plant performance is maintained over the life of the plant. This approach is also very dependent on the event selection process. For the purpose of siting and containment/confinement decisions, the staff recommends that conservative source terms for AOOs and DBEs be used. For EP purposes, a best-estimate source term would be reasonable.

In reiterating the concept of mechanistic source terms, the NRC staff stated in SECY-10-0034, "Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs," dated March 28, 2010, that "the staff will assess what will be necessary to establish the basis for a scenario-specific approach and how uncertainties should be taken into account. In addition, design and license applicants and the NRC will need to establish appropriate bounding source terms for high-temperature gas-cooled reactors (HTGRs)."

The staff noted a need to establish a technical basis for the mechanistic modeling of modular HTGR source terms in SECY-93-092 and again in SECY-03-0047. The technical basis for, and the uses of, such source terms are the subject of DOE/INL's FQ and MST white papers and the NRC's FQ-MST assessment report. Commission consideration of regulatory or policy issues may be appropriate in determining whether the site boundary dose acceptance criteria and associated dose calculations for use in the evaluation of site suitability and emergency planning for SMR designs should be revised or whether new requirements for SMRs should be established. Current regulatory practice employs the siting dose criteria in 10 CFR 50.34 and 10 CFR 52.79 in conjunction with deterministic DBA analyses as the key input parameters for analyzing the effectiveness of the containment and for determining site suitability.

In addition to considering appropriate accident source terms for specific advanced reactor designs, the evaluation of site suitability would include consideration of the population density; use of the site environs, including proximity to man-made hazards; and the physical characteristics of the advanced reactor site, including seismology, meteorology, geology, and hydrology.

Responses to DOE/INL Requests Concerning Mechanistic Source Terms

- ***DOE/INL Request: Endorse the proposed definition of NGNP mechanistic source terms (i.e., the quantities of radionuclides released from the reactor building to the environment during the spectrum of LBEs, including the timing, the physical and chemical forms, and the thermal energy of the release).***

DOE/INL's proposed definition of mechanistic source terms describes what is being released to the environment for assessing offsite dose consequences from accidents, normal operations, and other operational occurrences. Although DOE/INL defines source terms as releases from the reactor building, the proposed mechanistic analysis of source terms considers all barriers to release and therefore necessarily includes the calculation of releases from the primary system to the reactor building.

DOE/INL's accident source term definition is different from the traditional LWR accident source term in that it is not based on a severe core damage event. At a public meeting held in 2012, DOE/INL stated that the reference to substantial core melt in Footnote 6 of 10 CFR 50.34 does not apply to modular HTGRs. For the NGNP, releases to the reactor building would instead be based on a spectrum of limiting, mechanistically evaluated, risk informed LBEs supplemented by insights from credible bounding event sequences. Such bounding event sequences would take into account the safety behavior of the plant, and the associated fission product releases would be evaluated mechanistically.

DOE/INL's proposed definition generally aligns with the NRC staff's associated recommendation in SECY-93-092, which defined a mechanistic source term as follows:

> The result of an analysis of fission product release based on the amount of cladding damage, fuel damage, and core damage resulting from the specific accident sequences being evaluated. It is developed using best-estimate phenomenological models of the transport of the fission products from the fuel through the reactor coolant system, through all holdup volumes and barriers, taking into account mitigation features, and finally, into the environs.

In summary, the NRC staff concludes that DOE/INL's proposed definition of NGNP mechanistic source terms aligns with the current staff position on the treatment of advanced reactor mechanistic source terms and is thus reasonable for use in DOE/INL's proposed approach to determining licensing parameters for modular HTGRs.

- ***DOE/INL Request: Agree that NGNP source terms are event specific and determined mechanistically using models of radionuclide generation and transport that account for fuel and reactor design characteristics, passive features, and radionuclide release barriers.***

The NRC staff concludes that DOE/INL's proposed mechanistic approach to evaluating event-sequence-specific release source terms and resulting offsite dose consequences provides a reasonable basis for determining the licensing parameters for modular HTGRs. This approach is consistent with the Commission-approved staff positions on source terms in SECY-93-092 and SECY-03-0047.

- ***DOE/INL Request: Agree that NGNP has adequately identified the key HTGR fission product transport phenomena and has established acceptable plans for evaluating and characterizing those phenomena and associated uncertainties.***

The NRC staff's FQ-MST assessment report concludes, with caveats, that DOE/INL's ongoing and planned testing and research activities for NGNP fuel qualification and mechanistic source terms development appear to constitute a reasonable approach to establishing a technical basis for the identification and evaluation of key HTGR fission product transport phenomena and associated uncertainties. The staff expects more information on release and transport phenomena through event-sequence-specific pathways to be developed as DOE/INL's activities in these areas proceed. The discussion below on functional containment performance includes additional NRC staff comments on DOE/INL's approach to NGNP fuel qualification and mechanistic source terms development.

3. Functional Containment Performance

History of Pertinent NRC Staff and Commission Positions

In SECY-93-092, the staff recommended that containment designs should be evaluated against a functional performance standard instead of a prescriptive criterion, stating that functional containment designs must be adequate to meet the specified onsite and offsite radionuclide release limits for the event sequence categories within their design envelope. The Commission approved the staff's recommendation in the SRM to SECY-93-092.

In SECY-03-0047, the staff recommended that the Commission approve the use of functional performance requirements to establish the acceptability of containment (i.e., a non-pressure-retaining building may be acceptable, provided that performance requirements can be met). If approved by the Commission, the staff would develop the functional performance requirements using guidance contained in the Commission's SRM of July 30, 1993, and the Commission's guidance on the other issues discussed in SECY-03-0047. In the resulting SRM dated June 26, 2003, the Commission stated that it did not have sufficient information to determine the best options and to make a decision on the viability of a non-pressure-retaining building. The Commission directed the staff to develop functional performance requirements and criteria for containment while working closely with industry experts (e.g., designers, Electric Power Research Institute, etc.) and other stakeholders regarding options in this area, taking into account such features as the core, fuel, and cooling systems design. The Commission further directed the staff to pursue the development of functional performance standards for containment and then submit options and recommendations to the Commission on this policy issue.

In SECY-05-0006, the staff discussed many of the concepts developed in previous communications between the staff and Commission on the topic of functional containment performance and, as directed in the SRM to SECY-03-0047, outlined the attributes for a functional containment. The NRC staff concludes these attributes are applicable to the functional containment proposed by DOE/INL. Specifically, the functional containment should do the following:

- Protect risk-significant SSCs from internal and external events.
- Physically support risk-significant SSCs.
- Protect onsite workers from radiation.
- Remove heat to prevent risk-significant SSCs from exceeding design or safety limits.
- Provide physical protection (i.e., security) for risk-significant SSCs.
- Reduce radionuclide releases to the environs (including limiting core damage).

Additionally, consistent with options recommended in SECY-05-0006, the NRC staff would be open to evaluating functional containment performance based on a risk-informed analysis and mechanistic evaluation of selected credible licensing basis events for off-site dose analysis purposes and, with the caveats noted in SECY-05-0006, to establish credible events for emergency planning zone (EPZ) considerations. Staff views on functional containment requirements and performance evaluation for modular HTGRs may be further shaped by continuing developments in response to Fukushima Dai-ichi lessons.

Responses to DOE/INL Requests Concerning Functional Containment Performance

- ***DOE/INL Request: Confirm that the plans being implemented under the Advanced Gas Reactor (AGR) Fuel Development and Qualification Program (hereafter referred to as the AGR Fuel Program) are generally acceptable and that they provide reasonable assurance of the capability of coated particle fuel to retain fission products in a controlled and predictable manner. Identify any additional information or testing needed to provide adequate assurance of this capability, if required.***

Among the defining features of the modular HTGR design concept is its use of inert helium gas to cool a graphitic reactor core containing billions of tristructural-isotropic (TRISO) ceramic coated fuel particles. The design concept is further defined by its predominant use of inherent and passive design features (e.g., low power density, negative temperature coefficient, slender core geometry, passively cooled reactor vessel) to keep fuel operating and accident conditions within defined limits and by a safety case that emphasizes the resulting ability to limit radionuclide releases from the fuel over a broad spectrum of off-normal event sequences. The high-temperature radionuclide retention capability of the TRISO coated fuel particle is therefore recognized as a key element in the design and licensing of modular HTGRs.

The Commission has found the concept of functional containment generally acceptable, as indicated in the SRMs to SECY-93-092 and SECY-03-0047. However, approval of DOE/INL's proposed approach to functional containment for the modular HTGR concept, with its emphasis on passive safety features and radionuclide retention within the fuel over a broad spectrum of off-normal conditions, would necessitate that the required fuel particle performance capabilities be demonstrated with a high degree of certainty.

In its FQ-MST assessment report, the NRC staff provides detailed feedback on DOE/INL's ongoing and planned activities in the AGR Fuel Program. In summary, the staff views the proposed high-level approaches to NGNP fuel qualification and mechanistic source terms as generally reasonable. The staff observes that the fuel development and testing activities completed to date in the AGR Fuel Program appear to have been conducted in a rigorous manner and with early results that show promise towards demonstrating much of the desired retention capability of the TRISO particle fuel developed for NGNP. Moreover, the staff believes that the planned scope of activities in the AGR Fuel Program is reasonably complete within the context of pre-prototype fuel testing. As further discussed below, the staff nevertheless believes that additional information from special tests in the NGNP prototype would be needed for providing reasonable assurance that the coated particle fuel developed for NGNP can retain fission products in a controlled and predictable manner consistent with DOE/INL's stated preliminary goals for fuel radionuclide retention under NGNP operating and accident conditions.

The AGR Fuel Program proposes to derive TRISO fuel performance data solely from accelerated fuel sample irradiations in the Advanced Test Reactor (ATR), a water-cooled materials test reactor located at INL. The NRC staff concludes that the data provided by the AGR Fuel Program should be verified and supplemented by additional data from real-time fuel irradiations in a prototypic HTGR environment. Fuel irradiated in an HTGR neutron energy spectrum breeds and fissions more plutonium than in the ATR test spectra used in the AGR Fuel Program. Plutonium fission is known to be the predominant source of certain fission product elements (e.g., palladium, silver) that can penetrate TRISO particle coatings and potentially degrade their retentiveness and integrity. Moreover, the planned test irradiations in

the AGR Fuel Program are accelerated up to three times, thereby further reducing the potential for coating degradation from time-at-temperature effects of plutonium fission products.

The staff acknowledges that the AGR Fuel Program includes significant ongoing and planned research efforts to investigate the poorly understood phenomenology of silver and palladium interactions with TRISO coating layers. DOE/INL has stated that these research efforts may include examinations on fuel samples irradiated in the ATR at temperatures significantly above those normally expected during irradiation in an NGNP core. The staff would consider new insights emerging from such investigations in evaluating the potential fuel performance uncertainties associated with the initially unmet need for test data from real-time fuel irradiations in an HTGR neutron spectrum.

The staff believes that supplemental testing is necessary to address this issue and potentially other issues concerning fuel performance and fuel service condition uncertainties as discussed in the staff's FQ-MST assessment report. The FQ-MST assessment report comments on the potential roles of special fuel testing and surveillance programs in the NGNP prototype reactor (i.e., first-of-a-kind NGNP reactor module with special provisions for prototype testing) in verifying and supplementing the technical bases for NGNP fuel service conditions and fuel performance. The staff believes that invoking special prototype requirements and license conditions in accordance with 10 CFR 50.43(e)(2)[8] may provide an acceptable approach to NGNP licensing in view of the identified needs for supplemental data on fuel performance and fuel service conditions in the NGNP core. This approach is generally consistent with the plan set forth in 2008 in the joint DOE-NRC Licensing Strategy Report to Congress, which included the following statement:

> [T]he applicant submits a licensing application in FY 2013 for a prototype nuclear power plant (using 10 CFR 50.43(e)) that would be located at a remote INL site. The prototype may incorporate compensatory measures to address uncertainties in the design (caused by delayed demonstration testing).

For NGNP prototype licensing, the NRC would use conservatively evaluated pre-prototype-test fuel and core performance uncertainties as a basis for determining any additional requirements on design or operating parameters (e.g., staged trip set points, staged limits on core thermal power or core outlet temperatures) during the prototype testing period.

To be useful as such, the NGNP prototype reactor module should be full-scale and functionally identical to the anticipated standard reactor module design. The NGNP prototype module may nevertheless need special design and operational provisions to accommodate the placement and removal of temporary probes and sensors in the core and primary system during the testing period.

The NRC staff would expect the scope of NGNP prototype testing and surveillance to include at least the following:

- Post-irradiation examination and accident heatup testing on used fuel discharged from the prototype.
- Mapping of in-core and core-outlet temperatures during normal operation.

[8] Note that 10 CFR 52.79(e)(24) incorporates the requirements of 10 CFR 50.43(e).

- Tests to establish or verify detection thresholds for plausible core operating anomalies (e.g., core hot spots caused by local obstructions of helium flow).

Additional or optional prototype tests to confirm design and licensing analyses or reduce associated uncertainties may also include, among others:

- Mapping of core and system temperatures under controlled or simulated conditions of loss of forced cooling or loss of coolant pressure.
- Tests to further refine or validate selected fission product transport models.

Enclosure 1 to SECY-11-0112, "Staff Assessment of Selected Small Modular Reactor Issues Identified in SECY-10-0034," dated August 12, 2011, further discusses prototype licensing approaches.

- ***DOE/INL Request*: Establish options on functional containment performance standards as requested by the Commission in the SRM to SECY-03-0047 and as discussed further in SECY-05-0006.**

The concept of performance-based containment acceptability for a modular HTGR has been well established by the Commission in response to SECY-93-092 and SECY-03-0047. The Commission-approved performance-based containment concept specifically does not require a pressure-retaining shielded containment structure similar to that used in current large LWR plants. In its SRM to SECY-03-0047, the Commission directed the staff to pursue the development of containment functional performance standards and to submit options and recommendations to the Commission for a future policy decision.

SECY-05-0006 is a policy issue information paper that describes the staff's work on several issues that were considered in the development of a future technology-neutral framework for reactor licensing, including the Commission-requested efforts on containment functional performance. However, as with the other issues discussed in SECY-05-0006, the staff did not submit the technology-neutral functional containment performance requirements and criteria options outlined in SECY-05-0006 for a Commission policy decision. It may be appropriate for the Commission to review the specific criteria applied to evaluate a modular HTGR functional containment concept for both a prototype plant and subsequent standard plants.

Consistent with the positions presented in SECY-05-0006, the staff agrees with the following description of a performance standard for a functional containment, which DOE/INL provided during assessment interactions in July and October 2012 (ML12223A151, ML13198A115):

> The upper tier performance standard for the functional containment for the NGNP should be to ensure the integrity of the fuel particle barriers (i.e., the kernel and coatings of the TRISO-coated fuel particles) rather than to allow significant fuel particle failures and then need to rely extensively on other mechanistic barriers (e.g., the helium pressure boundary and the reactor building). This standard should be characterized by [the following]:
>
> - [Ensuring] radionuclide retention within fuel during normal operation with relatively low inventory released into the helium pressure boundary (HPB).

- Limiting radionuclide releases to the environs to meet the onsite and offsite radionuclide dose acceptance criteria (i.e., 10 CFR 50.34 and EPA PAGs) at the EAB with margin for a wide spectrum of off-normal event sequences.

- Maintaining the capability to establish controlled leakage and controlled release of delayed accident source term radionuclides.

An additional set of functional containment performance standards that the staff already accepted in SECY-05-0006 is to directly or indirectly accomplish the following accident prevention and mitigation safety functions:

- Protect risk-significant SSCs from internal and external events.
- Physically support risk-significant SSCs.
- Protect onsite workers from radiation.
- Remove heat to prevent risk-significant SSCs from exceeding design or safety limits.
- Provide physical protection (i.e., security) for risk-significant SSCs.

➢ ***DOE/INL Request: Establish a staff position to support a final determination on how LBEs will be considered for making plant siting and functional containment design decisions, taking into consideration the staff's previous position in SECY-95-299, "Issuance of the Draft of the Final Preapplication Safety Evaluation Report (PSER) for the Modular High-Temperature Gas-Cooled Reactor (MHTGR)," dated December 19, 1995, that improved fuel performance is a justification for revising siting source terms and containment design requirements. (In particular, DOE/INL asks the staff to provide an adaptation of the guidance that has generally been applied to LWRs for compliance with 10 CFR 100.21.)***

Compliance with 10 CFR 100.21 would require either interpreting part of the related footnote[9] in 10 CFR 50.34 as not directly applicable to modular HTGRs or alternatively requesting an exemption. Footnote 6 in 10 CFR 50.34 was established for large LWRs based on Technical Information Document (TID)-14844, "Calculation of Distance Factors for Power and Test Reactor Sites," issued March 1962, and has existed since the initial issuance of 10 CFR 100.11, "Determination of Exclusion Area, Low Population Zone, and Population Center Distance," on April 12, 1962 (27 FR 3509). Although 10 CFR 100.11 no longer applied to the licensing of power reactors after January 10, 1997, the NRC included the siting source term concept in similar footnotes attached to the portions of 10 CFR 50.34 and 10 CFR 52.79 that give siting dose reference values.

Current reactor siting criteria primarily encompass separate regulations for seismic and non-seismic considerations. A regulatory action taken in 1996[10] relocated source term and dose requirements from 10 CFR Part 100, "Reactor Site Criteria," to 10 CFR 50.34(a) for plant applications after 1997. Siting source term and dose criteria therefore apply to plant designs as required by 10 CFR 50.34. Notwithstanding the nexus that exists with atmospheric dispersion characteristic requirements in 10 CFR 100.21, "Non-Seismic Siting Criteria," an applicant for a

[9] See Footnote 6 in 10 CFR 50.34.

[10] "Reactor Site Criteria Including Seismic and Earthquake Engineering Criteria for Nuclear Power Plants," 65 FR 65157; December 11, 1996.

reactor site may obtain an early site permit (ESP) under 10 CFR 52.17(b) or 52.79(a). The requirements of 10 CFR 50.34(a) must be addressed in the plant design referenced in an application for a construction permit or combined license. This understanding of the applicability of 10 CFR 50.34(a) in relation to future applications for an ESP is maintained throughout these documents whenever "siting criteria" are cited.

The Statements of Consideration for 10 CFR 100.11 state that "applicants are free and indeed encouraged to demonstrate to the Commission the applicability and significance of considerations other than those set forth in the guides." Given advanced reactor designs for which core melt events are not physically credible, as purported for the modular HTGR design concept, such a demonstration may be useful to show the Commission that some event sequence other than a "substantial core melt" scenario would be sufficient to meet the intent of 10 CFR 52.79 in a combined license application.

Alternatively, either an interpretation of this aspect of the footnote(s) in 10 CFR 52.79, or an exemption from it, may be justified based on research, testing, analysis, and validation. During assessment interactions in September 2012, DOE/INL proposed the following interpretation to address the intent of the footnotes for siting source terms and Footnote 7 in 10 CFR 52.79(a)(2)(iv) for the engineered safety features of modular HTGRs (ML12263A086):

> The fission product release assumed for this evaluation should be based upon a major accident, hypothesized for purposes of site analysis or postulated from considerations of possible accidental events. Such accidents will be based on a spectrum of limiting, mechanistically evaluated, risk-informed LBEs supplemented by insights from credible (i.e., physically plausible) bounding event sequences. Such bounding event sequences will take into account the safety behavior of the plant, and the associated fission product release will be evaluated mechanistically.

The staff agrees that this interpretation of the footnotes on the siting source term and the design of engineered safety features is reasonable for modular HTGRs.

The staff's preapplication review of the MHTGR, as documented in NUREG-1338, followed an approach for including the evaluation of a set of staff-selected bounding events. The staff now believes that similar sets of bounding event sequences should be further evaluated for current modular HTGR designs. In addition, the SRM to SECY-93-092 indicates a need to better explore the potential for cliff-edge effects associated with the possibility of air and moisture ingress events that could result in significant graphite oxidation in the core and support structures. In this regard, the SRM specifically directs the staff to consider "chimney-effect" air ingress events (i.e., with concurrent helium pressure boundary breaks above and below the core). Considerations for the selection of bounding event sequences for plant siting and functional containment design evaluations should be informed by "safety terrain" insights from such exploratory studies and should reflect the Commission's PRA policy statement by blending the strengths of probabilistic and deterministic methods.

Event sequences with moisture ingress or large breaks in the primary pressure boundary may be found to maximize the pressure-driven prompt releases from the modular HTGR functional containment system. The selection of large break sizes and locations for use in siting analyses should be informed by critical examination of the plausibility of gross vessel failure in the modular HTGR conceptual designs under consideration for NGNP. The evaluation of longer term siting releases to the reactor building and environs should be based on a plausible large

break event sequence selected to bound the potential for air ingress into the primary system and the resulting air oxidation of graphitic core and support structures. The progression and consequences of such long-duration oxidation event sequences should be evaluated in terms of the release of activity previously bound in the affected graphitic materials and any potential to overheat fuel particles (due to the addition of exothermic oxidation energy) or expose fuel particle coatings to oxidation by air. Factors that significantly affect the long-term progression of such oxidation event sequences may include the rate of air in-leakage into the reactor building and the ability of passive design features of the building and primary system to delay or limit oxygen transport to the core and support structures.

In summary, the staff believes that siting source term event sequences for modular HTGRs should be deterministically selected to bound both the short-term and long-term releases of radionuclides beyond the primary helium pressure boundary. The selected siting event sequences should be physically plausible event sequences, and the resulting event-sequence-specific siting source terms should be mechanistically analyzed.

4. Emergency Preparedness

History of Pertinent NRC Staff and Commission Positions

Emergency Preparedness (EP) is a significant aspect of the NRC's defense-in-depth approach to nuclear regulation designed to protect public health and safety and the environment.

The NRC's predecessor, the U.S. Atomic Energy Commission (AEC), required nuclear power plant licensees to address EP starting in 1958. The AEC published TID-14844 to establish a computational method for distances and exposures associated with a general class of reactors. The AEC used TID-14844 to establish zones defined in 10 CFR Part 100, which required licensees to establish an exclusion area, low population zone, and population center distance around nuclear power plants.

NUREG-0396, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light-Water Nuclear Power Plants" (EPA 520/1-78-016), issued November 1978, introduces the conceptual basis for EPZs that could provide dose savings for a spectrum of accidents that could be associated with the PAGs described in the EPA-400-R-92-001, "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents," issued 1992.

The NUREG-0396 task force, which included staff from the NRC and EPA, also established EPZ distance criteria, issued in December 1978, based on the following elements:

- The EPZ should encompass those areas in which projected dose from DBAs could exceed the EPA PAGs.

- The EPZ should encompass those areas in which consequences of less severe Class 9 (core melt) accidents could exceed the EPA PAGs.

- The EPZ should be of sufficient size to provide for substantial reduction in early severe health effects in the event of the more severe Class 9 accidents.

The NRC incorporated these EPZ definitions into Appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities," to 10 CFR Part 50. Specifically, one of the 16 standards in 10 CFR 50.47(b)(11) states the following:

> Means for controlling radiological exposures, in an emergency, are established for emergency workers. The means for controlling radiological exposures shall include exposure guidelines consistent with EPA Emergency Worker and Lifesaving Activity Protective Action Guides.

In the SRM to SECY-93-092, the Commission stated the following:

> The staff should remain open to suggestions to simplify the emergency planning requirements for reactors that are designed with greater safety margins. To that end, the staff should submit to the Commission recommendations for proposed technical criteria and methods to use to justify simplification of existing emergency planning requirements.

The Commission further stated that work on EP should be closely correlated with work on accident evaluation and source terms to avoid unnecessary conservatism. In addition, the work on EP for advanced reactors should be coordinated with the approach for evolutionary and passive advanced reactors.

Subsequently, SECY-97-020 presents the staff's review of NUREG-0396 rationale, criteria, and methods and the evaluation of the rationale, criteria, and methods for EP for evolutionary and passive advanced LWRs. This review and evaluation enabled the staff to recognize the following statement as one of their conclusions:

> Changes to EP requirements may be warranted if the technical criteria for EP requirements were modified to account for the lower probability of severe accidents or the longer time period between accident initiation and release of radioactive material for most severe accidents associated with evolutionary and passive advanced LWRs.

SECY-11-0152, "Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors," issued October 28, 2011, includes the following consideration for establishing the size of EPZs for SMRs:

> The staff considers it appropriate to be open to applicant requests for establishing SMR technology-neutral, variable distance, plume exposure EPZs. However, the staff recognizes that the burden would be on the applicant to provide a well-justified basis for this section.

The NRC staff recognizes that new and advanced reactors may incorporate enhanced margins of safety or may use simplified, inherent, passive, or other innovative means to accomplish safety and security functions and to thereby address the expectations stated in the 1986 Commission policy statement on the regulation of advanced reactors (updated in 2008). To the extent that such safety and security improvements can be demonstrated for advanced designs, potentially including modular HTGRs, the NRC staff is open to considering alternative treatment of EP for advanced reactors. The regulations in 10 CFR 50.33(g) state that the size of the EPZs also may be determined on a case-by-case basis for gas-cooled reactors and for reactors with an authorized power level less than 250 MW thermal.

Responses to DOE/INL Requests Concerning Emergency Preparedness and Planning

- ***DOE/INL Request: Propose a new policy or revised regulations on how EPZ sizing can be scaled to be commensurate with the accident source term, fission product release, and associated dose characteristics.***

The key issues in this request are as follows:

- The use of the DOE/INL-proposed risk-informed, performance-based approach to calculate the frequency of exceeding the PAG values as a function of distance from the plant for a spectrum of accidents.
- The establishment of criteria for determining that the point at which the frequency of exceeding the PAG values is acceptably low.

In SECY-11-0152, the staff indicated a willingness to consider alternative EP requirements and frameworks for SMR facilities. SECY-11-0152 describes a PAG-based dose-distance scalable approach that could be considered for determining EPZs on a case-by-case basis for modular HTGRs.

The staff recognizes that design-specific policy issues may be associated with the approach suggested by DOE/INL for proposing a combined low population zone and EAB (or a scaled or reduced EPZ) partly based on event-specific release source terms calculated mechanistically for a spectrum of LBEs. For instance, one of the modular HTGR design goals is to not have any identified credible LBEs that result in severe core damage and associated large offsite radiological releases. Although the NRC staff may consider these issues in future prelicensing or licensing interactions, future Commission policy guidance may be appropriate for this topic.

- ***DOE/INL Request: Establish guidance on how the specific emergency planning requirements in 10 CFR Part 50 can be applied with a graded approach (when compared to current emergency plans for LWRs) that allows for the development of onsite and offsite emergency plans commensurate with the NGNP design and a plume exposure EPZ at a distance from the plant (e.g., approximately 400 meters from the reactor centerline) to demonstrate that it meets the PAG values.***

The NRC staff states in SECY-11-0152 that it considers it appropriate to be open to applicant requests for establishing technology-neutral, variable distance, plume exposure EPZs for SMRs. SECY-11-0152 describes a dose-distance scalable approach that could be emulated for determining SMR EPZs. In addition, SECY-10-0034 states that HTGR facilities belong to a technology group of SMRs that may be likely to submit a license application to the NRC.

The staff does not plan to provide additional guidance for specific changes to EP requirements in the absence of specific proposals from the NGNP applicant or nuclear industry. In December 2013, the Nuclear Energy Institute (NEI) submitted a white paper, “Proposed Methodology and Criteria for Establishing the Technical Basis for Small Modular Reactor Emergency Planning Zone.” The staff will have additional interactions with NEI on this topic. The staff expects that the license application would provide sufficient design information for the review of the proposed NGNP EP framework approach. The NRC does not expect that changes to regulations will be necessary to adopt a graded approach to EP requirements. However, the staff believes that

future Commission consideration may be appropriate for any proposed changes to established EP policy and guidance.

- ***<u>DOE/INL Request</u>: Propose guidance on how issues related to the modularity of the designs and the co-location of multiple-module plants near industrial facilities should be considered in emergency planning.***

The DOE/INL expects to co-locate the NGNP with industrial facilities. The plant would provide energy in the form of electricity and process heat to the co-located industrial facilities. Examples include petrochemical, oil refinery, chemical processing, coal liquefaction, hydrocarbon extraction, and hydrogen production industrial facilities.

EP issues related to licensing nuclear plants that are co-located with industrial facilities could be similar to those currently evaluated for the LWRs that are near industrial facilities. However, the staff believes that future Commission consideration may be appropriate if the intended usage differs significantly from existing practices, such as the Waterford 3 Steam Electric Station (Waterford) located near an industrial park in Killona, LA. The proximity of the industrial park requires Waterford to address NRC regulations related to the impact of potential industrial hazards, such as industrial chemical releases. Response plans incorporate this type of assessment to ensure the protection of nuclear plant safety systems, plant personnel, and the public.

License applications must consider the following issues that involve, among others, the use of nuclear process heat by co-located industrial facilities:[11]

- Safety implications and equipment protection associated with shared industrial facility SSCs.

- Standoff considerations of potential explosions and missiles or fires at the co-located industrial facilities.

- External events, such as aircraft impact, flooding, and seismic events, that affect the co-located industrial facilities.

- The effect of chemicals, gases, and radioactive hazards from industrial facilities.

- Response coordination with the co-located industrial facility and with State, Federal, and county agencies and resolution of jurisdictional issues.

- Radioactive material monitoring and plant security at the co-located industrial facilities.

[11] See the section entitled, “Industrial Facilities Using Nuclear-Generated Process Heat,” in SECY-11-0112.

SUMMARY AND CONCLUSIONS

As required by the EPAct, DOE/INL and the NRC staff have been engaged in a series of prelicensing interactions on the NGNP project since 2007. Prelicensing activities conducted since late 2009 have included the NRC staff's review of a series of DOE/INL white paper submittals that describe elements of DOE/INL's proposed approach for implementing the NGNP licensing strategy that DOE and NRC jointly developed and reported to Congress in 2008. Since February 2012, the latest set of interactions has focused on further resolving issues in four key areas for licensing the NGNP prototype. As clarified by DOE/INL in its letter of July 6, 2012, these four key issue areas are:

- Licensing basis event selection
- Source terms
- Functional containment performance
- Emergency preparedness

The NRC staff had previously provided DOE/INL with incremental feedback on its proposed NGNP licensing approach through public meeting interactions and public correspondence, including two preliminary NRC assessment reports on five related white paper topics. This summary feedback document, and the more detailed feedback in the NRC staff's updated FQ-MST assessment report, conclude that the proposed risk-informed framework and performance-based criteria for licensing the NGNP prototype present a generally reasonable approach for implementing the framework outlined in the joint NGNP Licensing Strategy Report of 2008, which includes the following major conclusion:

> The best approach to establish the licensing and safety basis for the NGNP will be to develop a risk-informed and performance-based technical approach that adapts existing NRC LWR technical licensing requirements in establishing NGNP design-specific technical licensing requirements. This approach uses deterministic engineering judgment and analysis, complemented by probabilistic risk assessment (PRA) information and insights, to establish the NGNP licensing basis and requirements. As discussed in this report, the selected approach provides significant advantages in meeting the schedule for licensing an NGNP while providing consistency with Commission policy guidance on the use of probabilistic risk information and insights.

Accordingly, the focus of the NRC staff's review has been primarily on (1) the general approach for applying the risk-informed, performance-based criteria to NGNP licensing and (2) a determination of how such an approach could be adaptable to current licensing requirements. A future application for NGNP licensing should specify the details of these adaptations, some of which may entail specific regulatory exemptions and policy issues for which Commission consideration may be appropriate.

The joint Licensing Strategy Report includes the use of the prototype testing provisions under 10 CFR 50.43(e). The prelicensing activities that the NRC conducted with DOE/INL since 2008 have reinforced and refined the staff's early views on the regulatory necessity and technical importance of testing and surveillance for the NGNP prototype. Additional requirements on design or operating parameters may be necessary during the testing period in the NGNP prototype that, subject to the successful completion of the required programs for testing and surveillance, may not be necessary for a standard NGNP design.

The NRC staff will generally determine what information the NGNP applicant must provide as part of the license application. The applicant will be responsible for providing any additional research data needed to support the NGNP safety case. The NRC will use the agency's resources if it believes that independent NRC research is important to independently assess the applicant's submittals or to provide the technical bases needed to develop the regulatory requirements.

As noted in the preceding sections and as further discussed in the staff's FQ-MST assessment report, the NRC staff believes that DOE/INL's proposed approaches to the respective key issues are generally reasonable and are responsive to the Commission's Policy Statement on advanced reactors. The staff notes that the NRC is currently engaged in efforts that may significantly affect the issue of LBE selection. The NRC staff has further identified technical and regulatory issues, such as EP, that could have policy implications for which future consideration by the Commission may be appropriate. Lastly, the NRC staff notes that further insights gained from future NGNP licensing efforts should benefit ongoing efforts to further risk-inform the existing reactor licensing framework and related longer term efforts to develop a new technology-neutral framework for reactor licensing.