October 28, 2010

CCN 222327
NRC Project #0748

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

SUBJECT: Contract No. DE-AC07-05ID14517 – Next Generation Nuclear Plant Project Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an High Temperature Gas Reactor – NRC Project #0748

Consistent with the actions identified in "NGNP Licensing Strategy – Report to Congress," dated August 2008, the purpose of this letter is to submit the subject Next Generation Nuclear Plant (NGNP) Project white paper for U.S. Nuclear Regulatory Commission (NRC) review as part of the early licensing phase of the project. The NGNP will be a licensed commercial high temperature gas-cooled reactor (HTGR) plant capable of producing electricity and high temperature process heat for a variety of energy intensive industries.

The NRC licensing process encourages early interactions to identify and resolve policy, regulatory, and key technical issues related to the proposed facility. Conducting effective interactions with the NRC is a critical part of the NGNP licensing strategy because the early resolution of issues can significantly impact the preparation of an acceptable license application, the subsequent application review schedule, and the ultimate deployment of the NGNP. This white paper represents one in a series of submittals that will address priority licensing topics related to establishing HTGR regulatory requirements.

The enclosed document, INL/MIS-10-19799, "*Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR*," summarizes the approach that will be undertaken to establish the appropriate plume exposure and ingestion pathway emergency planning zones for the HTGR. This approach was developed consistent with the provisions contained in 10 CFR 50, which allow for the size of these emergency planning zones to be considered on a case-by-case basis for gas-cooled reactors, including HTGRs. This paper also discusses how emergency planning requirements can be simplified by applying a graded approach to addressing guidance used in demonstrating compliance with existing regulatory requirements. This approach is consistent with the reduced risk associated with a HTGR reactor design with significantly enhanced safety margin, while maintaining the defense in depth concept. It is also noted that we have concluded that the described approach can be implemented within the current regulatory structure, and that no changes are required to existing regulatory requirements.

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Following NRC Staff review of this paper and pending resolution of associated follow-on questions or requests for additional information, the NGNP Project requests that NRC provide feedback and documentation of its review in a format that will facilitate resolution of HTGR emergency planning issues. The resolution of this matter will guide the preparation of future HTGR license application(s).

If you have any questions, please contact me at (208) 526-6063 or James Kinsey, Director, NGNP Regulatory Affairs at (208) 526-6882.

Sincerely,

Greg Gibbs, Project Director
Next Generation Nuclear Plant Project

TH:CN

Enclosure:

1. INL/MIS-10-19799, "*Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR.*"

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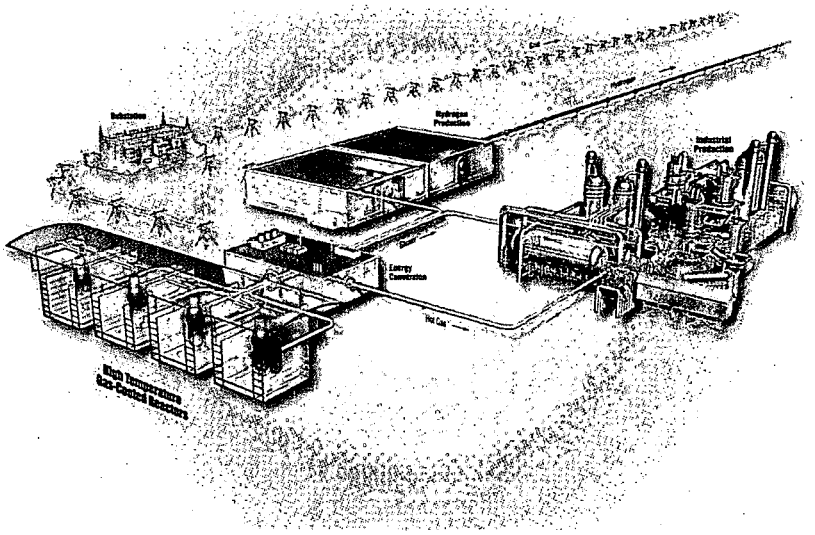
Revision 0

Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR

October 2010



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INL/MIS-10-19799
Revision 0

Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR

October 2010

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Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

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Next Generation Nuclear Plant Project

Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR

INL/MIS-10-19799

October 2010

Approved by:

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ABSTRACT

This white paper is one in a series of papers that addresses key priority licensing topics as part of the process for establishing regulatory requirements for the Next Generation Nuclear Plant (NGNP). The NGNP will be a commercial high temperature gas-cooled reactor (HTGR) plant capable of producing electricity and high temperature process heat for industrial markets supporting a range of end-user applications. The NGNP Project has adopted the 10 CFR 52 Combined License Application process, as recommended in the *NGNP Licensing Strategy – Report to Congress*, dated August 2008, as the foundation for its licensing strategy. Licensing of the NGNP by the U.S. Nuclear Regulatory Commission will demonstrate the efficacy of licensing future HTGRs for commercial industrial applications. This white paper summarizes the approach that will be undertaken to establish the appropriate plume exposure and ingestion pathway emergency planning zones for the HTGR. Provisions contained in 10 CFR 50 allow for the size of these emergency planning zones to be considered on a case-by-case basis for gas-cooled reactors, including HTGRs. This paper also discusses how emergency planning requirements can be simplified by applying a graded approach to addressing guidance used in demonstrating compliance with existing regulatory requirements. This approach is consistent with the reduced risk associated with a HTGR design with significantly enhanced safety margin, while maintaining the defense in depth concept.

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EXECUTIVE SUMMARY

The Next Generation Nuclear Plant (NGNP) Project was initiated at Idaho National Laboratory by the U.S. Department of Energy pursuant to the 2005 Energy Policy Act and based on research and development activities supported by the Generation IV Nuclear Energy Systems Initiative. The principal objective of the NGNP Project is to support commercialization of the high temperature gas-cooled reactor (HTGR) technology. The HTGR is helium cooled and graphite moderated that can operate at reactor outlet temperatures much higher than those of conventional light water reactor (LWR) technologies. Accordingly, it can be applied in many industrial applications as a substitute for burning fossil fuels, such as natural gas, in addition to producing electricity, which is the principal application of current LWRs.

The HTGR has safety characteristics, which stem from material, nuclear, and thermal hydraulic design and performance characteristics, that mitigate the severity of postulated licensing basis events (LBEs) (e.g., loss of coolant pressure, reactivity transients) and reduce the potential release of the associated radiological source terms and calculated dose consequences. Because the properties of the TRISO fuel and graphite moderator do not depend on the presence of coolant pressure, the core cannot physically melt. During postulated accident events involving core heat-up, a limited reduction in the effectiveness of the coated fuel particle radiological barriers in a small fraction of the core volume results only in limited (small) increases in radionuclide release from the fuel. These characteristics support one of the objectives of the HTGR safety basis, which is to limit the calculated dose from releases so that regulatory requirements for protection of the health and safety of the public and protection of the environment are met at an exclusion area boundary (EAB) that is no more than a few hundred meters from the reactor (e.g., 400 to 425 meters). Specifically, this is accomplished for the HTGR by demonstrating that the EPA Protective Action Guides (PAGs) for the early phase of an atmospheric release are not exceeded at the plant site's EAB. This will support the associated licensing objective of establishing the plume exposure emergency planning zone (EPZ) at the EAB and support flexibility in siting the HTGR plant with the objective of locating the HTGR in close proximity to industrial processes to improve the efficiency of energy transport to the processes. Additionally, by demonstrating that PAGs are not exceeded at the EAB, the HTGR will be able to establish an appropriate set of emergency planning requirements suitable for co-location with these industrial process facilities.

This white paper presents the approach to establishing the sizes of the plume exposure EPZ and ingestion pathway EPZ for a HTGR. The event-specific mechanistic approach that the NGNP Project is taking in developing radiological source terms for LBEs provides the basis for establishing the EPZ sizes. The mechanistic approach takes appropriate credit for the radionuclide retention capabilities of each of the multiple barriers to radionuclide release to the environment in developing the source terms needed for dose calculations supporting EPZ sizing. The deterministic methodology used for LWRs to establish source terms related to a severe core melt accident is not adequate to take into account these safety characteristics of HTGRs and would lead to EPZs that are larger than necessary and inappropriate for a HTGR. This white paper discusses information related to EPZ sizing sufficient to support HTGR licensing, including relevant elements of a fuel qualification program, mechanistic source term, performance of the HTGR functional containment, and overall defense-in-depth. The set of Outcome Objectives presented in this paper identifies technical and design information that will be needed to establish the appropriate EPZ sizes for an HTGR.

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ACRONYMS

ACRS	Advisory Committee on Reactor Safeguards
AOO	anticipated operational occurrence
BDBE	beyond design basis event
CDE	committed dose equivalent
CEDE	committed effective dose equivalent
CFR	Code of Federal Regulations
COL	Combined License
COLA	Combined License Application
CPG	Comprehensive Preparedness Guide
DBE	Design Basis Event
DDE	deep dose equivalent
DHS	Department of Homeland Security
DOE	Department of Energy
EAB	exclusion area boundary
EAL	Emergency Action Level
EDE	effective dose equivalent
EOP	Emergency Operations Plan
EP	emergency planning
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
EPZ	emergency planning zone
ESF	emergency support function
ESP	Early Site Permit
F-C	frequency-consequence (curve)
FEMA	Federal Emergency Management Agency
FHSR	Final Hazards Summary Report
FPT	fission-product transport
FR	Federal Register
FSV	Fort St. Vrain Nuclear Generating Station
HTGR	high temperature gas-cooled reactor
IC	initiating condition
INL	Idaho National Laboratory
LBE	Licensing Basis Events

LWR	light water reactor
NEI	Nuclear Energy Institute
NGNP	Next Generation Nuclear Plant
NOC	National Operations Center
NRC	Nuclear Regulatory Commission
NRF	National Response Framework
NRIA	Nuclear/Radiological Incident Annex
NUREG	Nuclear Regulatory Commission Technical Report Designation
PAG	Protective Action Guide
PAS	protective action strategies
PBMR	Pebble Bed Modular Reactor
PNNL	Pacific Northwest National Laboratory
PRISM	power reactor innovative small module
PSER	Pre-Application Safety Evaluation Report
QHO	quantitative health objectives
rem	roentgen equivalent man
RG	Regulatory Guide
R-I	risk-informed
SECY	Office of the Secretary of the Commission Document
SER	Safety Evaluation Report
SMR	small modular reactor
SOARCA	state-of-the-art reactor consequence analysis
SRM	Staff Requirements Memorandum
SRP	Standard Review Plan
SSC	structures, systems, and components
TEDE	total effective dose equivalent
TID	Technical Information Document
TRISO	Tristructural-Isotropic

1. Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR INTRODUCTION

The primary purposes of this white paper are to (1) describe the proposed approach for establishing emergency planning zone (EPZ) sizes for high temperature gas-cooled reactor (HTGR) design and licensing, (2) describe the impact on emergency planning based on EPZs smaller than those for light water reactors (LWRs), and (3) obtain input from the Nuclear Regulatory Commission (NRC) , regarding the acceptability of the proposed approach for establishing EPZ sizes for the plume exposure and ingestion pathways, subject to appropriate validation through the associated Next Generation Nuclear Plant (NGNP) Project activities.

In 2009, the NGNP Project performed an initial study on the regulatory history and current criteria to better define the specific regulatory criteria that apply to the definition of the plume exposure and ingestion pathway EPZ footprints and to establish an initial licensing strategy to address and resolve issues to facilitate implementation of the following criteria:

- Calculated doses from releases following licensing basis events (LBEs) are limited so that regulatory requirements for protection of the health and safety of the public and protection of the environment are met at an exclusion area boundary (EAB) that is no more than a few hundred meters from the reactor, and
- The expected (mean) offsite doses for accidents shall meet the Environmental Protection Agency (EPA) Protective Action Guides (PAGs).

Conclusions from that study suggested that there is a viable regulatory path for satisfying emergency planning requirements, while still achieving (1) a reduction of the plume exposure EPZ to the Exclusion Area Boundary (EAB); and (2) a reduction of the ingestion pathway EPZ (i.e., for which action may be required to protect the food chain) to a smaller size appropriate to the accident source terms from an HTGR.

This paper also summarizes key issues associated with establishing EPZ sizes and emergency planning requirements appropriate for an HTGR that need to be addressed and resolved as a part of the Combined License Application (COLA) process. The information provided herein is intended to serve as the basis for interactions with the NRC staff.

1.1 Objectives

The objectives of this paper are to:

- Summarize regulatory, technical, and policy issues for sizing the EPZ
- Identify NRC precedents involving gas-cooled reactors and LWRs
- Discuss the NGNP approach to EPZ sizing
- Present the rationale for applying a graded approach to addressing onsite and offsite emergency planning requirements more appropriate for an HTGR
- Discuss the applicability of LWR-derived emergency action levels (EALs) and initiating conditions (ICs) in relation to the HTGR.

1.2 Scope

The approach for establishing EPZ sizes discussed in this white paper applies to all HTGR plant designs being considered for the NGNP and is intended to be generic for the various HTGR commercialization strategies being considered. The methodology described in this white paper is based on the entire plant design-operation life cycle.

1.3 Statement of the Issues

The issues addressed in this paper are presented in terms of justifying an approach to emergency planning requirements that is consistent with policy, engineering, and programmatic considerations that reflect the design and operating characteristics of the HTGR envisioned by the NGNP Project. The issues are addressed in terms of the following premises:

- It is justifiable and desirable to appropriately size the plume and ingestion pathway EPZs and simplify emergency planning requirements for reactors that are designed with significantly enhanced safety margins. The HTGR design has no credible licensing basis events resulting in severe core damage and associated large offsite radiological releases that would justify the need for very large EPZs and extensive offsite response plans.
- The HTGR design places a greater emphasis on prevention through inherent and passive features to reduce the dependence on active systems thereby creating safety value without sacrificing defense-in-depth capability (INL 2009). Because of inherent design features of the HTGR, a significant reduction is achieved in the potential for an offsite radiological release. When we apply existing regulatory requirements to these technical details, we conclude that reliance on emergency planning can be reduced, when compared to an LWR.
- Emergency planning requirements can be simplified, when compared to current emergency plans for LWRs, by applying a graded approach to addressing guidance used in demonstrating compliance with existing regulatory requirements consistent with reduced risk associated with a reactor design with significantly enhanced safety margins. Planning standards such as organization and staffing, facilities, emergency classification, assessment, prompt notification, onsite and offsite response, training, and periodic drills and exercises should be addressed in a manner consistent with the design and operating characteristics of the HTGR.

1.4 Summary of Outcome Objectives

The objective of this paper is to solicit NRC feedback and agreement on the appropriate information related to EPZ sizing sufficient to support NGNP Project licensing. Relevant elements of NGNP Project white paper development, including fuel qualification, mechanistic source terms, and defense-in-depth, support the strategy for applying a graded approach to addressing guidance used in demonstrating compliance with emergency planning requirements outlined in this paper. The NGNP Project is seeking NRC's review and feedback on the overall approach to establish the EPZ sizes for the HTGR and to obtain feedback from the NRC on any emergency planning issues that have the potential to significantly impact the effort and schedule to prepare a COLA for a first-of-a-kind HTGR plant under the NGNP Project. The following are specific areas where agreement on the NGNP Project approach to establish the EPZ size is being sought:

1. Application of the defense-in-depth methodology (INL 2009) developed for the HTGR provides a foundation for technical justification for EPZ sizing because of a resulting set of conservative design features that, combined with inherent reactor characteristics, are designed to (1) prevent transients and accidents, (2) ensure the performance of safety functions, (3) prevent the release of radioactive material, and (4) mitigate the consequences of accidents.
2. The design and operating characteristics of the HTGR support the development of emergency planning requirements that are consistent with the significantly enhanced safety margins and reduced risk associated with the reactor design.
    a. The mechanistic source term approach, and radionuclide inventories elsewhere in the facility that are determined during source term analysis, can be used to establish EPZ sizes. The mechanistic approach to source term development establishes the technical basis and takes appropriate credit

for the radionuclide retention capabilities of each of the multiple barriers to radionuclide transport to the environment consistent with the HTGR safety design approach.

b. A significant release of radioactive material is prevented through fuel design that consists of a multiple-coating-layer system that has been engineered to retain the fission products generated by fission of the nuclear material in the fuel during normal operation and all licensing basis events over the design lifetime of the fuel. Although plant defense in depth depends on many factors, the tri-structural isotropic (TRISO) -coated fuel is particularly critical to the prevention of radiological releases because the fuel particles are the primary (but not the only) barrier to fission-product release in HTGRs.

3. Confirmation that EPZ sizing should be determined, in part, from evaluation of offsite dose consequences of design basis events (DBEs) and design basis threats to determine the distance at which the lower limit EPA PAGs are met for each event scenario.

4. Concurrence that technical justification for the appropriate EPZ size should be based on the absence of a significant radiological release during an accident thus allowing offsite emergency response to be accommodated, in part, through all-hazards plans, which may already exist for industrial process facilities.

5. Compliance with the emergency planning requirements in 10 CFR 50 can be established and confirmed on a graded approach, when compared to current emergency plans for LWRs, that allows for site and offsite emergency plans to be developed commensurate with the HTGR design. For example:

   a. Simplification of onsite and offsite emergency response organization
   b. Potential reduction of on-shift staffing requirements
   c. Offsite fire/rescue and medical facility capabilities consistent with existing industrial hazard plans (with the addition of a nuclear/radiological incident annex if needed)
   d. Potential reduction in number of participating agencies and jurisdictions
   e. Potential reduction in the need for prompt notification
   f. Consolidation and simplification of emergency response facilities
   g. Offsite response and protective action strategy commensurate with the risk and potential impact of a radiological release
   h. Simplification of training, exercise, and drill requirements.

1.5 Relationship to Other NGNP Topics/Papers

This white paper for sizing the EPZ and specifying emergency planning attributes is one of several white papers covering key regulatory issues that are being prepared and submitted for NRC review and discussion as part of the NGNP Project licensing strategy. Several of these other white papers have direct bearing on the planned approach for establishing emergency planning requirements and EPZ sizes. The papers that have the most direct relationship with this paper include:

- Defense-in-Depth Approach
- Mechanistic Source Terms
- Fuel Qualification
- Licensing Basis Events Selection
- Nuclear/Industry Boundary and Co-location.

The white paper on mechanistic source terms presents information that is particularly significant to EPZ sizing for the HTGR and is summarized below. Throughout this paper, other white papers are

referenced to support information presented on emergency planning and EPZ sizing. Figure 1 in the Licensing Basis Events Selection White Paper (INL 2010b) provides a graphic representation of the inter-relationships of the various applicable white papers.

1.5.1 Mechanistic Source Terms White Paper

The NGNP *Mechanistic Source Terms White Paper* (INL 2010) "presents the event-specific[a] mechanistic approach that the NGNP Project is taking in developing radiological source terms[b] for LBEs. The source terms developed with this approach, and the radionuclide inventories elsewhere in the facility that are determined during source term analysis, can also be used for other purposes, including equipment environmental qualification, control room habitability analyses, and assessments of accident risks in environmental impact statements. The mechanistic approach takes into account the inherent characteristics of the HTGR technology that provide multiple barriers to fission product transport to the environment in developing the source terms. The deterministic methodology used by LWRs to establish source terms related to a severe core melt accident is not adequate to take these safety characteristics into account for HTGRs."

Of particular significance to establishing the EPZs for the HTGR is obtaining agreement with the NRC staff "...that the safety basis of the HTGR precludes core damage and, therefore, focuses on limiting the release of significant amounts of radioactive material as a result of non-core damage event sequences that could occur with this design. The calculation of the source term for these conditions requires validating the characteristics and integrity of barriers to transport and release of radionuclides from the plant under LBEs. Accordingly, assuming a large fission-product release from the core due to a severe accident (i.e., an accident comparable to a substantial core melt in a LWR) is not credible for an HTGR and need not be considered when defining LBEs" (INL 2010b). This concept directly impacts dose calculations needed for demonstrating compliance with EAB and low population zone criteria, as well as establishing the size of the EPZ.

The safety objectives of the HTGR are described in Section 2.3.1 of the *Mechanistic Source Terms White Paper* (INL 2010) and are considered throughout the approach discussed in this paper for establishing the size of the EPZs for the HTGR:

> *The HTGR safety basis supports the same objective as that of the LWRs—designing, constructing, maintaining, and operating the plant to ensure the health and safety of the public and workers and protection of the environment under all normal, abnormal, and postulated accident conditions. However, the HTGR safety basis is different from that of the currently licensed LWRs, which focuses on preventing and mitigating core damage and large early release of radionuclides in the event of core damage. The safety basis of the HTGR, however, precludes core damage sufficient to significantly affect radiological*

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a. Although the process for defining and selecting licensing basis events is the subject of a white paper that is currently under review by the NRC, it is expected, based on previous modular gas-cooled reactor safety analyses, that there will be no single limiting LBE for the HTGR. The conditions in the reactor core and the plant vary in time and space for each LBE and a source term is calculated for each event; thus the identification of the source terms as event-specific. The approach for the development of the source term for each LBE is based on establishing the effectiveness of the barriers to fission-product transport under the plant conditions for each event calculated from the material, nuclear, and thermal hydraulic characteristics of the HTGR.

b. As used in this white paper, *source term* refers to the quantities, timing, physical and chemical forms, and thermal energy of radionuclides (used herein interchangeably with fission products) released from the reactor building to the environment during postulated accidents. Traditionally, the expression source term can also have broader meanings. For example, in LWRs the source term refers to the quantities of radionuclides released to the containment building under accident conditions. Source term may also refer to the quantities of radionuclides that must be shielded when a shipping cask is designed or to the concentrations of radionuclides deposited on a steam generator tube bundle when the gamma dose rates associated with tube plugging are calculated.

consequences and, therefore, focuses on preventing and limiting the release of relatively small amounts of radioactive material as a result of event sequences that could occur with this design. The calculation of the source terms for these conditions is event-specific and requires validating the characteristics and integrity of barriers to transport and release of radionuclides from the plant for each event.

An objective of the safety basis is to limit a calculated dose from releases so that regulatory requirements for protection of the health and safety of the public and protection of the environment are met at an EAB that is no more than a few hundred meters from the reactor (e.g., 400 to 425 meters). This will support the associated licensing objective of establishing the plant EPZ at the EAB. This then supports flexibility in siting the HTGR plant with the objective of locating the HTGR in close proximity to industrial processes to improve the efficiency of energy transport to the processes.

The *Mechanistic Source Terms White Paper* discusses the specific characteristics of HTGRs that contribute to their safety characteristics, including:

- A large solid graphite moderator/reflector structure with very high temperature capability
- A passive heat transfer path from the fuel to the ultimate heat sink (e.g., the reactor cavity cooling system)
- A large negative temperature coefficient that limits reactor power levels to relatively low levels under accident conditions without control rod or reserve shutdown system insertion of negative reactivity
- A low core power density and high core surface to volume ratio that limits the fuel temperature rise in the most limiting conditions of loss-of-forced cooling and depressurization of the primary coolant system
- A single-phase, chemically inert, neutronically transparent, and low-heat-capacity helium coolant with low stored energy, minimizing the requirement for containment of energy in a postulated breach of the helium pressure boundary.

Limiting licensing basis event transients occur over hours and days, not seconds. No fast-acting active safety systems are required to maintain the fuel within design limits. The characteristics discussed above are significant to emergency planning because the absence of rapidly escalating events that lead to severe core damage precludes the need for prompt public actions in the event of an emergency at a HTGR.

Section 3 of this paper presents a summary of the safety objectives of the HTGR and the effect on offsite emergency planning.

2. REGULATORY FOUNDATION

2.1 Regulatory Framework

NRC regulations require detailed emergency plans for nuclear power plant operators, including jurisdictions within the plume exposure EPZ. These regulations support longstanding Commission policy and are supported by implementing guidance and NRC technical reports. This section discusses the overall regulatory framework related to EPZ sizes and emergency planning for nuclear power plants.

2.1.1 NRC Requirements

2.1.1.1 Siting Regulations

The first step in considering sizing of the plume exposure EPZ and the ingestion pathway EPZ is to consider the regulatory requirements associated with siting and the related design considerations of nuclear power plants promulgated in Title 10 Code of Federal Regulations (CFR) Part 100, "Reactor Siting Criteria," and Part 50, "Domestic Licensing of Production and Utilization Facilities." Two concepts that are discussed throughout this paper are defined in 10 CFR 100.3 and 10 CFR 50.2 as follows:

> *Exclusion area means that area surrounding the reactor, in which the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area. This area may be traversed by a highway, railroad, or waterway, provided these are not so close to the facility as to interfere with normal operations of the facility and provided appropriate and effective arrangements are made to control traffic on the highway, railroad, or waterway, in case of emergency, to protect the public health and safety. Residence within the exclusion area shall normally be prohibited. In any event, residents shall be subject to ready removal in case of necessity. Activities unrelated to operation of the reactor may be permitted in an exclusion area under appropriate limitations, provided that no significant hazards to the public health and safety will result.*
>
> *Low population zone means the area immediately surrounding the exclusion area which contains residents, the total number and density of which are such that there is a reasonable probability that appropriate protective measures could be taken in their behalf in the event of a serious accident. These guides do not specify a permissible population density or total population within this zone because the situation may vary from case to case. Whether a specific number of people can, for example, be evacuated from a specific area, or instructed to take shelter, on a timely basis will depend on many factors such as location, number and size of highways, scope and extent of advance planning, and actual distribution of residents within the area.*

10 CFR 100.21(a) provides the requirement that every reactor site must have an *exclusion area* as defined in 10 CFR 100.3. 10 CFR 50.34(a)(1) includes requirements with respect to radiological doses to individuals in the *exclusion area* and *low population zone* for reactor license applicants. 10 CFR 50.34(a)(1)(ii)(D) specifically requires that:

> *The applicant shall perform an evaluation and analysis of the postulated fission product release...The evaluation must determine that:*
>
> *(1) An individual located at any point on the boundary of the exclusion area 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).

(2) 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 total effective dose equivalent (TEDE.)

Although the applicable portions of Part 100 are silent regarding multiple reactor facilities, insight into the considerations for how multiple HTGRs at a site will be addressed is provided in 10 CFR 100.11(b)(1), which specifies that consideration should be given to the following:

If the reactors are independent to the extent that an accident in one reactor would not initiate an accident in another, the size of the exclusion area, low population zone and population center distance shall be fulfilled with respect to each reactor individually. The envelopes of the plan overlay of the areas so calculated shall then be taken as their respective boundaries.

10 CFR 100.20 also includes factors to be considered when evaluating the interrelationship between nuclear and non-nuclear facilities. 10 CFR 100.20 provides the following requirements:

(a) Population density and use characteristics of the site environs, including the exclusion area, the population distribution, and site-related characteristics must be evaluated to determine whether individual as well as societal risk of potential plant accidents is low, and that physical characteristics unique to the proposed site that could pose a significant impediment to the development of emergency plans are identified.

(b) The nature and proximity of man-related hazards (e.g., airports, dams, transportation routes, military and chemical facilities) must be evaluated to establish site parameters for use in determining whether a plant design can accommodate commonly occurring hazards, and whether the risk of other hazards is very low.

Finally, 10 CFR 100.21(c)(2) states that:

Site atmospheric dispersion characteristics must be evaluated and dispersion parameters established such that: Radiological dose consequences of postulated accidents shall meet the criteria set forth in § 50.34(a)(1) of this chapter for the type of facility proposed to be located at the site.

2.1.1.2 Emergency Planning Regulations

Emergency planning requirements associated with licensing a nuclear power plant are contained in 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities," and 10 CFR 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." 10 CFR 52.77 requires that a COLA must include all of the general information required by10 CFR 50.33. The following specific requirements related to emergency planning are included in subparagraph §50.33(g):

Generally, the plume exposure pathway EPZ for nuclear power reactors shall consist of an area about 10 miles (16 km) in radius and the ingestion pathway EPZ shall consist of an area about 50 miles (80 km) in radius. The exact size and configuration of the EPZs surrounding a particular nuclear power reactor shall be determined in relation to the local emergency response needs and capabilities as they are affected by such conditions as demography, topography, land characteristics, access routes, and jurisdictional boundaries.

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. The plans for the ingestion pathway shall focus on such actions as are appropriate to protect the food ingestion pathway.

Specific content requirements for emergency plans are provided in 10 CFR 50.47 and Appendix E to 10 CFR 50. As provided in 10 CFR 50.33(g), the case-by-case sizing allowance for determining the EPZ for gas cooled reactors is included in 10 CFR 50.47(c)(2) and in Appendix E to 10 CFR 50.

10 CFR 50.47(b) provides 16 standards that must be included in nuclear power plant emergency plans. Additional regulatory requirements related to these standards are provided in Appendix E to Part 50. Implementing guidance presented in NUREG-0654/FEMA-REP-1, includes 17 planning standards and associated evaluation criteria. NUREG-0654 is discussed further in Section 2.1.3.

For an Early Site Permit (ESP) application, 10 CFR 52.17(b) provides requirements for emergency planning information that must be provided. Pertinent emergency planning requirements for COLAs are provided in 10 CFR 52.79(a). While neither of these regulations discuss EPZ size specifically, they both defer to §50.47 and Appendix E to Part 50 for content requirements for emergency plans.

2.1.2 SECY Papers and NRC Policy

The NRC's general policy is to publicly release written issue papers submitted by the NRC staff to the Commission for consideration. Policy, rulemaking, and adjudicatory matters, as well as general information, are provided to the Commission for consideration, in part, through documents that are referred to as "SECY papers." Over the years, the NRC staff and Commission have reviewed a variety of emergency planning issues that are applicable to licensing of the HTGR. This section discusses pertinent SECY papers important to developing an acceptable approach to establishing the EPZs for the HTGR.

In SECY 90-0341, *Staff Study on Source Term Update and Decoupling Siting from Design* (NRC 1990), the staff presented the conclusions and sought commission approval with regard to updated source term information and whether reactor siting could be decoupled from plant design. This study recommended decoupling design and siting and included several proposals: (1) revising the standard accident source term contained in TID-14844, and (2) modifying Parts 50 and 100 to allow siting to be based on criteria that were not explicitly tied to the source term suggested in TID-14844.

This study has essentially been completed with subsequent revisions of Parts 50 and 100 and with the definition of the new alternate source term. Under these provisions, the actual criteria based on dose are essentially unchanged (25 rem [roentgen equivalent man]) though the specific organ dose has been eliminated. The key difference is that the dose calculation requirements now specifically allow for analysis of a more realistic source term and allows credit for "fission product cleanup systems in dose reduction" as put forward in SECY 90-0341. Philosophically, SECY 90-0341 was important in establishing the basis for the regulatory changes that have subsequently been implemented. However, in the discussion contained in Enclosure 1 to the SECY, it is explicitly stated that, "Decoupling will not result in significant changes in reactor siting criteria. (The principal objective of this effort is to change the basis for evaluating certain Engineered Safety Feature designs.)"

The philosophy allowing decoupling of design and siting is tempered by the Commission's regulations in 10 CFR 100.1(d), which states, "The Commission intends to carry out a traditional defense-in-depth approach with regard to reactor siting to ensure public safety. Siting away from densely populated centers has been and will continue to be an important factor in evaluating applications for site approval."

SECY 97-0020, *Results of Evaluation of Emergency Planning for Evolutionary and Advanced Reactors* (NRC 1997), is the NRC staff's response to a Commission request for the staff to perform an evaluation to develop technical criteria and methods for emergency planning for evolutionary and

advanced reactor designs. The evaluation focused on the evolutionary and passive advanced LWR designs because of the availability of design and risk assessment data and because applicants were pursuing certification of these designs. The staff determined the rationale that emergency planning for current LWR designs is based upon potential consequences from a spectrum of accidents, which is appropriate for use as the basis for emergency planning for evolutionary and passive advanced LWR designs. The staff also saw no need to pursue smaller EPZ sizes because of the expected applications for new reactors being sited at plant sites that already had emergency plans. The staff indicated this rationale to be consistent with the Commission's defense-in-depth safety philosophy.

Pertinent information that bears consideration for establishing the EPZ sizes for the HTGR can be found in SECY 97-0020, which states:

> *The staff also recognizes that changes to EP requirements may be warranted if the technical criteria for the 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.*

Although the focus of SECY 97-0020 is on LWRs, the NRC staff noted three issues in their discussion that are pertinent to establishing the EPZ sizes for the HTGR. Other subsequent SECY papers expand further on NRC staff needs related to HTGR emergency planning, as discussed in the remainder of this section.

> *In order to justify these types of changes to the EP basis, the staff believes that several issues, which would require significant expenditure of staff resources, need to be addressed: (1) the probability level, if any, below which accidents will not be considered for EP, (2) the use of increased safety in one level of the defense-in-depth framework to justify reducing requirements in another level, and (3) the acceptance of such changes by Federal, State, and local emergency response agencies.*

For the Pebble Bed Modular Reactor (PBMR), SECY 02-0139, *Plan for Resolving Policy Issues Related to Licensing Non-Light Water Reactor Designs* (NRC 2002), specifically addresses the issue, "Under what conditions, if any, can emergency planning zones be reduced, including a reduction to the site exclusion area boundary?" While Attachment 7 to SECY 02-0139 provides the following discussion regarding EPZ sizing and emergency planning requirements appropriate to the PBMR, no Commission Staff Requirements Memorandum (SRM) was issued.

> *The PBMR proposal seeks to establish a probabilistic cutoff (using the safety goal early fatality quantitative health objective) for events that need to be considered for emergency planning purposes. This differs from the basis used to establish the current 10 mile EPZ for LWRs in that the full range of accidents were considered and a 10 mile distance chosen as the point where doses to the public large enough to cause early fatalities rapidly diminish.*
>
> *To arrive at a recommendation on the policy issue, the staff will consider the following:*
>
> - *Should there be minimum requirements for emergency evacuation as part of the defense-in-depth philosophy, regardless of plant design or projected risk and if so, what should they be?*
> - *To what extent should probabilistic criteria be used to define the events to be considered for emergency planning and if so, what should they be?*

- *Are projected doses to individuals that are less than the EPA-PAGs sufficient to use as criteria to establish the EPZ?*
- *What demonstration of plant performance, if any, would be necessary to find such a proposal acceptable?"*

SECY 03-0047, *Policy Issues Related to Licensing Non-Light-Water Reactor Designs* (NRC 2003), contains "recommendations for Commission consideration on seven technical policy issues identified in the pre-application reviews to date on non-LWR designs. The seven issues involve the approach to licensing on key aspects of reactor design and operation which relate to Commission policy and practice and which could impact the viability of future non-LWR designs." Issue 7 addresses conditions identified by the NRC staff that would need to be satisfied to reduce the EPZ sizes, including a reduction in the EAB. The staff states the role of emergency planning in defense-in-depth should be addressed as part of the development of a policy or description of defense-in-depth. In the following discussion, the NRC staff identifies the conditions that should be met:

> *Emergency preparedness is considered by many to be the last line of defense in the defense-in-depth philosophy. Its requirements have been established in consideration of the potential for accidents that could lead to severe core damage and the subsequent release of large amounts of radioactive material. For LWRs this release could occur in a matter of hours after the initiating event and a 10-mile plume exposure pathway EPZ has been chosen to envelope the distance beyond which it is very unlikely doses large enough to cause early fatalities would occur. In considering whether or not to modify the EPZ, similar considerations would need to be taken into account. These could include:*
>
> - *What is the potential for a severe core damage accident?*
> - *What is the potential for a large offsite release of radioactive material?*
> - *Should the assumption of a large offsite release be a fundamental part of defense-in-depth?*
> - *How should the characteristics of the release be used to set the EPZ (e.g., potential for early fatalities, timing of release)?*
> - *How should uncertainties and experience with the design and technology be taken into account?*

In its SRM on SECY 03-0047, the Commission approved the staff's recommendations, including issue 7.

SECY 03-0059, *NRC's Advanced Reactor Research Program* (NRC 2003a), discusses the scope of NRC's research on advanced reactor designs. Of relevance to EPZ sizing is information addressed under the discussion on severe accident and source term analysis:

> *As part of NRC's review of advanced reactors, the development of FP transport and source terms will play an important part in several policy issues, such as the need for leak tight containments, the need for and size of emergency planning zones, and the choice of design basis accidents. There is a need for data and modeling methods for the new materials and configurations that will be used in the advanced reactors (particularly in HTGRs). Research will be needed to support both the development of infrastructure to perform confirmatory analysis and to identify and resolve many of the source term-driven policy issues discussed above.*

SECY 03-0059 goes on to discuss consequence analysis research:

Offsite consequence analysis is the final aspect of PRA, the so-called Level 3. The mix of radionuclides and the chemical forms in the releases from severe accidents occurring in advanced reactors may be different from those in releases during accidents in light-water reactors. Therefore, comparisons of present and advanced technologies are likely to require the comparison of full Level 3 analyses. Past evaluations of light-water reactor technology issues have often stopped at the stage of large early release frequency.

With respect to applying the research, the paper discusses the following:

Research results would be incorporated into NRC's Level 3 code, MACCS2. Independent confirmation of risk (probability times consequence) will be available to NRC reviewers. For instance, a technical justification for a recommendation to the Commission on the policy question of the size of the Emergency Planning Zone (EPZ) may be needed. The supporting calculations need to be commensurate with the calculations utilized in choosing the current 10-mile EPZ for today's light-water reactor plants. These calculations are referred to in NUREG-0654 (Federal Emergency Management Agency-REP-1), "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants." The choice of the size of the EPZ is also discussed in this document. The calculations are discussed more fully in NUREG-0396 (EPA 520/1-78-016), "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light-Water Nuclear Power Plants."

SECY 03-0059 indicates that technical justification may be needed for the NRC to consider the policy question on the size of the EPZ. While the SECY paper indicates that this justification includes supporting dose calculations consistent with those calculations used to establish the current 10-mile EPZ for large LWRs, additional considerations are discussed in other SECY papers. The other issue discussed in the SECY paper is a "large early release." Section 3 of this paper provides the methodology for establishing the EPZs for the HTGR, including dose calculations and the characteristics of a release.

NRC staff discusses their efforts on developing a paper on the *Regulatory Structure for New Plant Licensing, Part 1: Technology-Neutral Framework* 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* (NRC 2005), NRC staff notes that there are difficult technical and policy issues that the staff is addressing with the development and implementation of this new licensing structure. Two issues are pertinent to HTGR EPZ sizing: use of scenario-specific source terms for licensing decisions; and possible modifications of emergency preparedness requirements. With regard to the latter issue, SECY 05-0006 states:

The Commission approved the staff proposal that no change to emergency preparedness requirements is needed in the near term. The Commission also approved, for the longer term, the staff developing guidelines for assessing possible modifications to emergency preparedness requirements as part of the work to develop a description of defense-in-depth. At the present time, the staff has developed a conceptual approach for assessing changes to emergency preparedness, consistent with defense-in-depth considerations. The conceptual approach is to ensure a baseline emergency preparedness capability, regardless of reactor technology or design, and to expand this baseline where necessary to accommodate the need for more rapid implementation.

The most current Commission paper, SECY 10-0034, *Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs* (NRC 2010a), reports on a number of potential policy

and licensing issues discussed in preapplication meetings with the U.S. Department of Energy (DOE). Topics relevant to HTGR emergency planning and EPZ sizing are: appropriate source term, dose calculations, performance of HTGR functional containment, siting for small modular reactors, and offsite emergency planning. The following discussions are excerpted from SECY 10-0034:

> *Appropriate Source Term, Dose Calculations, and Siting for SMRs*
>
> *Accident source terms are used for the assessment of the effectiveness of the containment and plant mitigation features, site suitability, and emergency planning. Other radiological source terms are used to show compliance with regulations on dose to workers and the public. Design and license applicants and the NRC will need to establish appropriate bounding source terms for high-temperature gas-cooled reactors and other SMRs. There may also be source-term issues associated with the multi-module aspect of SMRs where modules share structures, systems, and components (SSCs). For example, the Commission may have to determine when it would be appropriate to base the bounding source term on an accident in a single module and when possible sharing of SSCs require the evaluation of core damage in and potential releases from more than one module. In FY 2010 and FY 2011, the NRC staff will review pre-application submittals concerning source-term issues that it receives from DOE and potential SMR applicants, discuss design-specific proposals to address this matter, and consider research and development in this area (both by the domestic and the international community). Should it be necessary, the staff will propose changes to existing regulations or propose new regulatory guidance concerning the source term and site suitability for an SMR in FY 2011 to support development of the NGNP and other SMR designs.*
>
> *There may be regulatory issues that the Commission may have to consider regarding whether the site boundary dose acceptance criteria and associated dose calculations for use in evaluation of site suitability and emergency planning for SMR designs should be updated or amended, or whether new requirements should be established for SMRs. Current regulatory practice employs the siting dose criteria in 10 CFR 50.34 and 10 CFR Part 52 in conjunction with deterministic design basis accident analyses as the key input parameters for analyzing the effectiveness of the containment, determining site suitability, and preparing site emergency plans.*
>
> *Offsite Emergency Planning Requirements for SMRs*
>
> *In SECY-93-0092, the NRC staff questioned whether applicants for licenses referencing advanced reactors with passive design safety features should be able to adjust emergency planning zones (EPZs) and requirements. The staff proposed no changes to the existing regulations governing emergency planning for advanced reactor licensees, and stated that it would provide regulatory direction at or before the start of the design certification phase so that emergency planning implications on the design can be addressed. In its SRM dated July 30, 1993, the Commission stated that it was premature to reach a conclusion on emergency planning for advanced reactors and directed the NRC staff to use existing regulatory requirements. However, it instructed the staff to remain open to suggestions to simplify the emergency planning requirements for reactors that are designed with greater safety margins.*

In SECY 10-0034, NRC staff stated that the Commission instructed the staff to remain open to suggestions to simplify emergency planning requirements for reactors that are designed with greater

safety margins. The staff will consider white papers or topical reports proposing deviations from emergency preparedness requirements.

2.1.3 NRC Guidance

The concept of EPZs incorporated into the current requirements and guidance for nuclear power plants emergency planning was introduced in NUREG-0396, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants" (NRC 1978), in 1978. NUREG-0396 discusses generic EPZs "as a basis for the planning of response actions which would result in dose savings in the environs of nuclear facilities in the event of a serious power reactor accident." The size of the EPZs was agreed upon by a Task Force and their rationale is described as follows:

> *Several possible rationales were considered for establishing the size of the EPZs. These included risk, probability, cost effectiveness and accident consequence spectrum. After reviewing these alternatives, the Task Force chose to base the rationale on a full spectrum of accidents and corresponding consequences tempered by probability considerations. These rationales are discussed more fully in Appendix I. The Task Force agreed that emergency response plans should be useful for responding to any accident that would produce offsite doses in excess of the PAGs. This would include the more severe design basis accidents and the accident spectrum analyzed in the RSS. After reviewing the potential consequences associated with these types of accidents, it was the consensus of the Task Force that emergency plans could be based upon a generic distance out to which predetermined actions would provide dose savings for any such accidents. Beyond this generic distance it was concluded that actions could be taken on an ad hoc basis using the same considerations that went into the initial action determinations.*
>
> *The Task Force judgment on the extent of the Emergency Planning Zone is derived from the characteristics of design basis and Class 9 accident consequences. Based on the information provided in Appendix I and the applicable PAGs a radius of about 10 miles was selected for the plume exposure pathway and a radius of about 50 miles was selected for the ingestion exposure pathway, as shown in Table 1. Although the radius for the EPZ implies a circular area, the actual shape would depend upon the characteristics of a particular site. The circular or other defined area would be for planning whereas initial response would likely involve only a portion of the total area.*
>
> *The EPZ recommended is of sufficient size to provide dose savings to the population in areas where the projected dose from design basis accidents could be expected to exceed the applicable PAGs under unfavorable atmospheric conditions. As illustrated in Appendix I, consequences of less severe Class 9 accidents would not exceed the PAG levels outside the recommended EPZ distance. In addition, the EPZ is of sufficient size to provide for substantial reduction in early severe health effects (injuries or deaths) in the event of the more severe Class 9 accidents.*

2.1.3.1 Regulatory Guide 1.101, NUREG-0654/FEMA-REP-1

Regulatory Guide (RG) 1.101, "Emergency Planning and Preparedness for Nuclear Power Reactors" (NRC 2004a), provides methods acceptable to the NRC staff for complying with emergency planning regulations previously discussed in this paper. Currently, three versions of RG 1.101 are effective: Revision 3, Revision 4, and Revision 5. Revisions 3 and 4 differ only in that each endorses a different

version of industry guidance related to EALs used for emergency classification. Revision 5 provides guidance relative to conducting emergency response planning activities and interactions in the years between participation in the offsite full or partial participation exercises with offsite authorities, co-located licensees and co-located applicants. RG 1.101 is important to the discussion of emergency planning for the HTGR because it endorses NUREG-0654, which provides the licensing basis for nuclear plant emergency planning.

NUREG-0654/FEMA-REP-1, Revision 1, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants" (NUREG-0654) (NRC 1980), was issued to provide guidance and "upgraded acceptance criteria" as a basis for NRC licensee and state and local government development of radiological emergency plans and to improve emergency preparedness. NUREG-0654 is still applicable to current plant licensing activities and endorses the EPZ concept from NUREG-0396. The following footnote, consistent with regulatory provisions in §50.47, is provided in NUREG-0654:

> *These radii are applicable to light water nuclear power plants, rated at 250 MWt or greater. The FEMA/NRC Steering Committee has concluded that small water cooled power reactors (less than 250 MWt) and the Fort St. Vrain gas cooled reactor may use a plume exposure emergency planning zone of about 5 miles in radius and an ingestion pathway emergency planning zone of about 30 miles in radius. In addition, the requirements for the alerting and notification system (Appendix 3) will be scaled on a case-by-case basis. This conclusion is based on the lower potential hazard from these facilities (lower radionuclide inventory and longer times to release significant amounts of activity for many accident scenarios). The radionuclides considered in planning should be the same as recommended in NUREG-0396/EPA-520/1-78-016.*

Important to the consideration of EPZ sizing for the HTGR, NUREG-0654 provides the following guidance:

> *The size (about 10 miles radius) of the plume exposure EPZ was based primarily on the following considerations:*
>
> *a. projected doses from the traditional design basis accidents would not exceed Protective Action Guide levels outside the zone;*
>
> *b. projected doses from most core melt sequences would not exceed Protective Action Guide levels outside the zone;*
>
> *c. for the worst core melt sequences, immediate life threatening doses would generally not occur outside the zone;*
>
> *d. detailed planning within 10 miles would provide a substantial base for expansion of response efforts in the event that this proved necessary.*
>
> *The size of the ingestion exposure EPZ (about 50 miles in radius, which also includes the 10-mile radius plume exposure EPZ) was selected because:*
>
> *a. the downwind range within which contamination will generally not exceed the Protective Action Guides is limited to about 50 miles from a power plant because of wind shifts during the release and travel periods;*
>
> *b. there may be conversion of atmospheric iodine (i.e., iodine suspended in the atmosphere for long time periods) to chemical forms which do not readily enter the ingestion pathway;*

c. *much of any particulate material in a radioactive plume would have been deposited on the ground within about 50 miles from the facility; and*

d. *the likelihood of exceeding ingestion pathway protective action guide levels at 50 miles is comparable to the likelihood of exceeding plume exposure pathway protective action guide levels at 10 miles.*

Table 1 of NUREG-0654 summarizes "Guidance on the Size of the Emergency Planning Zone:"

Accident Phase	*Critical Organ and Exposure Pathway*	*EPZ Radius*
Plume Exposure Pathway	*Whole Body (external)* *Thyroid (inhalation)* *Other organs (inhalation)*	*about 10 mile radius**
Ingestion Pathway	*Thyroid, whole body, bone marrow (ingestion)*	*about 50 mile radius***

* *Judgment should be used in adopting this distance based upon considerations of local conditions such as demography, topography, land characteristics, access routes, and local jurisdictional boundaries.*

** *Processing plants for milk produced within the EPZ should be included in emergency response plans regardless of their location.*

Table 2 of NUREG-0654 provides "Guidance on Initiation and Duration of Release:"

Time from the initiating event to start of atmospheric release	*0.5 hours to one day*
Time period over which radioactive material may be continuously released	*0.5 hours to several days*
Time at which major portion of release may occur	*0.5 hours to 1 day after start of release*
Travel time for release to exposure point (time after release)	*5 miles – 0.5 to 2 hours* *10 miles – 1 to hours*

2.1.3.2 Regulatory Guide 1.206

RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)" (NRC 2007b), provides guidance to ESP and COL applicants regarding the content of emergency planning information required by 10 CFR 50 and 10 CFR 52. Notably this guidance is currently only applicable to LWRs, as indicated by the title of the RG. The NGNP Project has initiated actions, as summarized in the NGNP Licensing Plan, to develop guidance for HTGR license applicants that is expected to be similar in format to RG 1.206

2.1.3.3 Regulatory Guide 4.7

RG 4.7, "General Site Suitability Criteria for Nuclear Power Stations" (NRC 1998), discusses the major site characteristics related to public health and safety and environmental issues that the NRC staff considers in determining the suitability of sites for LWR nuclear power stations. Guidance is provided on EAB and low population zone determination, population center requirements, and emergency planning related to nuclear power reactor siting.

2.1.3.4 NUREG-0800

NRC's Standard Review Plan (SRP) for nuclear power plant applications, including ESPs and COLs, is provided in NUREG-0800 (NRC 2007). The NRC staff has provided the following direction related to their review of applicant emergency planning information in SRP Section 13.3:

> *The review is conducted against the applicable standards and requirements in 10 CFR 50.33, 10 CFR 50.34, 10 CFR 50.47, 10 CFR 50.54, 10 CFR 50.72, Appendix E to 10 CFR Part 50, 10 CFR Part 52, 10 CFR 73.71, and 10 CFR Part 100. The review is also conducted against any additional requirements that impact emergency planning and preparedness, including those associated with security, and are imposed through Nuclear Regulatory Commission (NRC) Orders. The review addresses plans for emergency response activities, including emergency planning zones (EPZs), emergency action levels (EALs), evacuation time estimates (ETEs), and emergency response facilities. If applicable, the reviewer also evaluates proposed inspections, tests, and analyses applicable to emergency planning that the licensee shall perform, and the associated acceptance criteria (i.e., ITAAC).*

As indicated in SRP 13.3, acceptable methods for complying with NRC emergency planning requirements are provided in RG 1.101.

2.1.4 Federal Emergency Management Agency Regulations

The Federal Emergency Management Agency (FEMA) is responsible for regulatory aspects of state and local government radiological emergency preparedness and maintains a Memorandum of Understanding with the NRC regarding division of responsibilities between the two agencies. The pertinent regulations are summarized below for general information, but also emphasize the influence FEMA has with respect to offsite emergency planning for commercial nuclear power plants and the importance of their engagement in establishing the EPZs for the HTGR.

44 CFR 350 establishes policy and procedures for review and approval by FEMA of state and local emergency plans and preparedness for the offsite effects of a radiological emergency which may occur at a commercial nuclear power facility. Review and approval of these plans and preparedness involves preparation of findings and determinations of the adequacy of the plans and capabilities of state and local governments to effectively implement the plans.

44 CFR 351 sets out federal agency roles and assigns tasks regarding federal assistance to state and local governments in their radiological emergency planning and preparedness activities. Assignments in this part apply to radiological accidents at fixed nuclear facilities and transportation accidents involving radioactive materials.

44 CFR 352 applies whenever state or local governments, either individually or together, decline or fail to prepare offsite radiological emergency preparedness plans for commercial nuclear power plants that are sufficient to satisfy NRC licensing requirements or to participate adequately in the preparation, demonstration, testing, exercise, or use of such plans.

Appendix A to 44 CFR 353 provides the Memorandum of Understanding that establishes a framework of cooperation between FEMA and the NRC in radiological emergency response planning matters so that their mutual efforts will be directed toward more effective plans and related preparedness measures at and in the vicinity of nuclear reactors and fuel cycle facilities subject to 10 CFR 50, Appendix E, and certain other fuel cycle and materials licensees which have potential for significant accidental offsite radiological releases.

2.1.5 U.S. Environmental Protection Agency Protective Action Guides

NUREG-0654 refers to PAGs issued by the EPA in 1980 (EPA-520/1-75-001) (EPA 1980). EPA updated these guidelines in EPA-400-R-92-001, *Manual of Protective Action Guides for Nuclear Incidents* (EPA 1992). The Manual provides levels of exposure to radiation at which public protective action should be taken. With regard to the relationship between the PAGs and establishing EPZ size, the Manual states:

> *It is not appropriate to use the maximum distance where a PAG might be exceeded as the basis for establishing the boundary of the EPZ for a facility. For example, the choice of EPZs for nuclear power facilities has been based primarily on consideration of the area needed to assure an adequate basis for local response functions and in the area in which acute health effects could occur. These considerations will also be appropriate for use in selecting EPZs for most other nuclear facilities. However, since it will usually not be necessary to have offsite planning if PAGs cannot be exceeded offsite, EPZs need not be established for such cases.*

Several tables in the manual provide PAGs based on the potential radiation dose to the public. For the purpose of this paper, the distance at which the following doses will not be exceeded will be used to establish the plume exposure EPZ:

- 1 rem total effective dose equivalent (TEDE). TEDE is the sum of the effective dose equivalent (EDE) from external radiation exposure to the plume and the committed effective dose equivalent (CEDE) from inhalation of radioactive material in the plume.
- 5 rem committed dose equivalent (CDE) to the thyroid. CDE is determined from inhalation of iodine radioisotopes in the plume. Typically, I-131 is used as the limiting radioisotope of iodine.

Establishing the ingestion pathway EPZ will rely on PAGs associated with the intermediate phase (e.g., days up to about one year beyond the early phase). The "preventive" PAGs for the protection of food and water and the exposure of population, provided in Chapter 3 and 6 of the manual, that can be applied for the ingestion EPZ are:

- 0.5 rem TEDE.
- 1.5 rem CDE to the thyroid.

2.2 Other References

2.2.1 NRC Licensing Strategy – Report to Congress

The *NGNP Licensing Strategy – Report to Congress* (DOE/NRC 2008), dated August 2008 does not directly address offsite emergency planning or EPZ sizing. This report discusses alternatives for the NGNP licensing process, within which the emergency planning approach described in this paper can be implemented.

2.2.2 NRC Strategic Plan

NRC publishes their Strategic Plan in NUREG-1614. Periodic updates are published as new volumes. The NRC's strategic plan was initially published for Fiscal Years 2000 through 2005 (NRC 2000). Updates were provided for Fiscal Years 2004 through 2009 (NRC 2004) and Fiscal Years 2008 through 2013 (NRC 2008). The Strategic Plan emphasizes NRC's goal of protecting public health and safety and the environment. Important to establishing the EPZ sizes for all nuclear power plant designs, including the HTGR, are five strategic outcomes provided in NUREG-1614, Volume 4:

- *Prevent the occurrence of any nuclear reactor accidents.*

- *Prevent the occurrence of any inadvertent criticality events.*
- *Prevent the occurrence of any acute radiation exposures resulting in fatalities.*
- *Prevent the occurrence of any releases of radioactive materials that result in significant radiation exposures.*
- *Prevent the occurrence of any releases of radioactive materials that cause significant adverse environmental impacts.*

Also important to establishing EPZ sizing is the Strategic Plan's definition of defense-in-depth:

> *Defense in Depth: an element of the NRC's Safety Philosophy that employs successive compensatory measures to prevent accidents or lessen the effects of damage if a malfunction or accident occurs at a nuclear facility. The NRC's safety philosophy ensures that the public is adequately protected and that emergency plans surrounding a nuclear facility are well conceived and will work. Moreover, the philosophy ensures that safety will not be wholly dependent on any single element of the design, construction, maintenance, or operation of a nuclear facility.*

Details regarding defense-in-depth for the HTGR are addressed in *Next Generation Nuclear Plant Defense-in-Depth Approach* white paper (INL 2009).

2.2.3 Development of a Risk-Informed and Performance-Based Update to 10 CFR Part 50 Requirements

The paper, *Next Generation Nuclear Plant Defense in Depth Approach* (INL 2009), provides information directly related to risk-informed and performance-based update to 10 CFR Part 50 requirements. As noted in that paper, in SECY 09-0056, *Staff Approach Regarding a Risk-Informed and Performance-Based Revision to Part 50 of Title 10 of the Code of Federal Regulations and Developing a Policy Statement on Defense-in-Depth for Future Reactors* (NRC 2009), the NRC staff summarized the development of a technology-neutral regulatory framework. Emergency planning is integral to the defense-in-depth philosophy, but no regulatory initiatives related to emergency planning or EPZ sizing for new reactor technologies are discussed in the NRC staff's technology-neutral regulatory framework presented in NUREG-1860 (NRC 2007a).

In May 2009, NRC proposed extensive changes to nuclear power plant emergency planning requirements. None of the proposed changes affect EPZ sizing, but they will have a significant impact on existing operating plant emergency plans and those associated with ESP and COL licensing activities. Broadly, the proposed rule changes fall into two categories: changes related to security (e.g., post-9/11 considerations) and non-security changes.

The increased focus of the NRC on response to hostile action events is a key consideration in the strategy developed in this paper for EPZ sizing.

2.2.4 Advisory Committee on Reactor Safeguards Recommendations

Information from various letter reports by the Advisory Committee on Reactor Safeguards (ACRS) was reviewed dating back to 1999. Relevant excerpts from these reports are provided in this section. Limited information directly discussing ACRS positions and recommendations on emergency planning is available. ACRS has held numerous discussions on related topics such as seismic hazards, hostile action, and quantitative health objectives. The ACRS has generally agreed with NRC staff on their handling of emergency planning matters.

Periodically, the ACRS provides a formal report that presents the observations and recommendations of the ACRS concerning the NRC Safety Research Program being carried out by the Office of Nuclear Regulatory Research. This report is issued in sequential volumes of NUREG-1635. In the most recent draft, Volume 9 dated March 2010 (NRC 2010), the ACRS provided the following discussion related to emergency planning and nuclear power plant safety:

> *Earthquakes of greater magnitude have the potential to damage the power plant and barriers to radionuclide release. Earthquake damage can be a common cause mechanism for the failure of methods to prevent accidents and methods to mitigate accidents – extending even to the final line of defense in depth of public evacuation and emergency planning.*

In November 2008, ACRS issued a white paper entitled, *Historical Perspectives and Insights on Reactor Consequence Analysis* (ACRS 2008). This paper is of particular interest to emergency planning for the HTGR because current EPZ sizes for LWRs are based on risk assessment studies from the mid-1970s. ACRS discusses state-of-the-art reactor consequence analysis, which is directly related to emergency planning considerations for the HTGR:

> *The NRC staff is currently implementing its plan for developing state-of-the-art reactor consequence analyses [U.S. NRC, "Plan for Developing State-of-the-Art Reactor Consequence Analyses," SECY-05-0233, December 22, 2005]. This work will: (1) evaluate and update, as appropriate, analytical methods and models for realistic evaluation of severe accident progression and offsite consequences; (2) develop state-of-the-art reactor consequence assessments of severe accidents; and (3) identify mitigative measures that have the potential to significantly reduce risk or offsite consequences. These analyses include external events; consideration of all mitigative measures, including the newly required extreme damage state mitigative guidelines (B.5.b); state-of-the-art accident progression modeling, based on 25 years of research, to provide a best estimate for accident progression, containment performance, time of release, and fission product behavior; more realistic offsite dispersion modeling; and site-specific evaluation of public evacuation based on updated emergency plans.*
>
> *In the April 14, 2006 SRM [Memorandum to Luis A. Reyes, Executive Director for Operations, NRC, from Kenneth R. Hart, Acting Secretary, NRC; Subject: Staff Requirements – SECY-05-0233-Plan for Developing State-of-the-Art Reactor Consequence Analyses, dated April, 14, 2006], the Commission specifically instructed the staff to "work with the ACRS on technical issues such as identification of accident scenarios to be evaluated, evaluation of source terms, credit for operator actions or plant mitigation systems, modeling of emergency preparedness, modeling of offsite consequences, and definition and characterization of analysis uncertainty."*

The ACRS white paper refers to a study conducted by the Electric Power Research Institute (EPRI), *Risk-Informed Evaluation of Protective Action Strategies for Nuclear Plant Off-Site Emergency Planning*, dated September 2007 (Leaver 2007). The EPRI study was undertaken to assess the effectiveness of offsite protective action strategies (PASs) for radiological emergencies at commercial nuclear power plants. Two specific objectives of the project are of interest to emergency planning for the HTGR:

- *To develop a risk-informed (R-I) methodology for quantifying the relative effectiveness of various off-site PASs. Depending on the effectiveness and practicality of the implementation by the off-site response organization (ORO) and the public, these strategies could then be considered for use in the emergency planning (EP) process for nuclear power plants.*

- *To provide an updated technical basis for EP, including consideration of an R-I approach and quantification of the margin in the 10-mile emergency planning zone (EPZ) required in the regulations.*

The conclusions in the report are mainly related to risks associated with the current generation LWRs, which are not directly relevant to the HTGR. What is of interest is the R-I methodology for quantifying the relative effectiveness of various offsite PASs. The methodology requires specific information regarding source terms and releases during accidents at a nuclear plant and may be a helpful tool for establishing the EPZs for the HTGR as the technology matures.

In their April 2007 letter, *Technology-Neutral Framework for Future Plant Licensing* (ACRS 2007), ACRS discusses the NRC's efforts towards developing a technology-neutral framework for future nuclear plant licensing. Such a framework would apply to emergency planning requirements, but is of no immediate impact to HTGR licensing. The following information from the April 2007 letter is useful in providing insight into developing information needed by the NRC staff to establish the EPZs for HTGRs.

> *The current regulations evolved over many years and addressed issues as they arose (a largely bottom-up approach). The prospect of applications for licensing non-light-water reactor designs presents an opportunity to produce a regulatory system that utilizes modern technology such as probabilistic risk assessment, incorporates lessons learned from the past, and is based on general principles (i.e., following a top-down approach). This top-down approach should be developed on a technology-neutral basis from which technology-specific requirements will be derived. This will ensure consistency among requirements for different designs and among requirements for a specific design, as well as make the intent of the regulations more transparent. Without a common technology-neutral framework, it will be necessary to develop a similar regulatory basis for each separate technology, an alternative that would be significantly less efficient. In the near term, an additional benefit would be derived for licensing applications that use existing regulations with some modifications. These modifications could be guided by the technology-neutral framework.*
>
> *The framework represents a major advancement in the development of a coherent risk-informed approach to establishing regulatory requirements for either future or current reactors. At this critical juncture, the staff should complete the framework. We look forward to continuing to work with the staff to resolve certain issues associated with the framework.*
>
> *Pebble Bed Modular Reactor (Pty) Ltd. has submitted a number of white papers (References 3 through 6) that outline potential elements of an approach to certifying the PBMR design. Since the PBMR design also represents a significant departure from a light-water reactor design, it is a logical choice on which to test the completed framework.*

In 2004, ACRS discussed the regulatory structure for the technology-neutral framework for licensing future nuclear plants (ACRS 2004). With regard to emergency planning, the discussion focused mainly on 10 CFR 52 conforming changes to the SRP (NUREG-0800) and lessons learned from large-scale evacuations. There appears to be no consideration given to future non-LWR designs that would not require large-scale evacuation.

In their December 2006 letter, "Proposed Revision to Standard Review Plan Section 13.3, "Emergency Planning"" (ACRS 2006), the ACRS noted:

The proposed revision to SRP Section 13.3, "Emergency Planning," incorporates the new reactor licensing processes codified in 10 CFR Part 52. Although this revision is a restructure and rewrite of the existing SRP Section 13.3, it does not contain any new or un-reviewed staff positions in the area of emergency planning.

Evacuation planning is integral to emergency preparedness. In the December 2006 ACRS letter on a draft revision to SRP Section 13.3, the ACRS noted the following with respect to weaknesses identified in evacuation planning during non-nuclear events:

Recent evacuations related to non-nuclear events have shown weaknesses in evacuation plans. The staff is reviewing these experiences for any applicable lessons learned. We support the staff's plan to follow-up with the Department of Homeland Security's Federal Emergency Management Agency (DHS/FEMA) to identify applicable lessons learned from experiences of evacuating large numbers of people (e.g., fire at the hazardous waste site in Apex, North Carolina, and Hurricane Katrina).

In their April 2004 letter, *Options and Recommendations for Policy Issues Related to Licensing Non-Light Water Reactor Designs* (ACRS 2004), the ACRS included the following discussion of quantitative health objectives (QHOs):

We agree with the staff that the QHOs are intended to protect the population around a site from the risk due to all reactors and spent fuel storage facilities on that site. Meeting the site QHOs will depend on the site's total number of plants and their design and power levels and the resulting risk will be the sum of risks from all contributors.

The issue of integrated risk has ramifications for the technology-neutral regulatory framework that is being developed by the staff. We understand that the preliminary proposal for this framework is to develop frequency-consequence (F-C) risk goals as a surrogate for the QHOs and to also deal with higher frequency incidents. Once again, an "achieved" F-C value would be a site characteristic and would depend not only on meteorology and population but on the design, number of units, and power levels at the site. For comparison with any goal, the composite F-C risk goals for the site will be required. The staff should keep this in mind in developing the technology-neutral framework.

2.2.5 NRC Precedents Involving HTGRs

2.2.5.1 Peach Bottom

The Peach Bottom Unit 1 HTGR, a 115-megawatt thermal (MWth), 40 megawatt electric (MWe) power station, operated from 1967 to 1974. Its Class 104 operating license was granted based in part on the *Final Hazards Summary Report* (Philadelphia Electric Company 1964). The Peach Bottom *Final Hazards Summary Report* used a conservative source term based on mechanistic release phenomena that reflected the time-dependent nature of HTGR fuel release during a severe accident. Because Peach Bottom ended operation in 1974 before the imposition of the emergency planning recommendations of NUREG-0396 in 1978, that were used as the basis for 10 CFR 50.47 finalized in 1980, no EPZs were established for the plant.

2.2.5.2 Ft. St. Vrain

The Fort St. Vrain Nuclear Generating Station (FSV) was a prismatic fuel HTGR that generated 842 MWth to achieve a net output of 330 MWe. FSV operated from 1974 to 1989 and was licensed using a deterministic source term based on TID-14844 (DiNunno et al. 1962). Two design basis accidents were

presented in the FSV *Final Safety Analysis Report* (Public Service Company of Colorado 1991) and represented an early effort to use a more mechanistic source term approach for a medium-sized HTGR. The applicant did not consider TID-14844 values to be applicable to the HTGR system, but a mechanistic source term was compared to TID-14844 assumptions to demonstrate the relative safety of the HTGR.

In recognition of the accident response characteristics of FSV, the plume exposure pathway EPZ and the ingestion pathway EPZ radii for the facility were set at 5 and 30 miles, respectively, instead of the normal 10 and 50 miles for LWRs. In addition, variances were approved for other aspects of FSV Emergency Planning. Most notably, the required response time for the Emergency Response Coordinator (the time in which the coordinator was required to reach the control room after being called to the plant for emergency response) was increased to 2 hours rather than the 30-minute response time required for LWRs.

2.2.5.3 Modular High-Temperature Gas-Cooled Reactor

NUREG-1338, "Draft Preapplication Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor," presents the preliminary results of a preapplication design review for a standard modular high temperature gas cooled reactor and was issued in 1989 (NRC 1989). This NUREG was updated and reissued in 1995 (NRC 1995). In the updated NUREG, the NRC staff discusses several policy issues related to advanced reactor designs and evolutionary and advanced LWRs that are applicable to the HTGR design. Of these issues, the staff noted that accident selection and evaluation is an important consideration to relaxing offsite emergency planning requirements for advanced reactors:

> *Information obtained from accident evaluations conducted, as outlined in Section 5.2.1 above, will be factored into the emergency planning requirements for advanced reactors. Based in part upon these accident evaluations, the staff will consider whether some relaxation from current requirements may be appropriate for advanced reactor offsite emergency plans. The relaxations to be considered will include, but will not be limited to, notification requirements, size of the EPZ, and frequency of the exercises, and will take into account the Commission policy decisions on passive LWR emergency planning.*

NUREG-1338 also addresses containment performance and source term, which are two other policy issues important to establishing the EPZ size. These two issues are integral to the accident selection and evaluation policy issue and are addressed in other HTGR white papers. Additionally, NUREG-1338 specifically refers to NUREG-1368.

NUREG-1368, "Preapplication Safety Evaluation Report for the Power Reactor Innovative Small Module (PRISM) Liquid-Metal Reactor" (NRC 1994), documents the NRC review of the PRISM conceptual design. Section 3.1.2.4 discusses offsite emergency planning. The NUREG notes that the pre-applicant asserts:

> *...that the PRISM design, with its passive reactor shutdown and cooling systems, and with core heatup times much longer than those of existing LWRs is sufficiently safe that the EPZ radius can be reduced to the site boundary, and that detailed planning and exercising of offsite response capabilities need not be required by NRC regulation.*

The staff concludes, however, that:

> *...once information is obtained from accident evaluations conducted by pre-applicants and licensees, it will be factored into the emergency planning requirements for advanced reactor designs. Based in part upon these accident evaluations, the staff will consider whether some relaxation from current requirements may be appropriate for advanced reactor offsite emergency plans.*

The relaxations the staff may evaluate include, but are not limited to, size of the EPZ, the frequency of exercises, and notification requirements.

2.2.6 NRC Precedents Involving LWRs

As noted previously in this paper, all LWRs with a thermal power rating of 250 MWth or greater are required to have a plume exposure EPZ of about 10 miles and an ingestion pathway EPZ of about 50 miles. Several smaller LWRs were operating for a period of time after these requirements were implemented, including Big Rock Point and the LaCrosse Boiling Water Reactor. Both plants had full-size EPZs. The operating licenses for these plants have been terminated and the facilities have been decommissioned.

2.3 Regulatory Basis Summary

Existing NRC emergency planning regulations and guidance are based primarily on LWR technology. Important to the HTGR is the specific provision in 10 CFR 50.33(g) and 50.47(c)(2) that allows the EPZ size for gas-cooled reactors to be considered on a case-by-case basis. NRC regulations provide 16 standards that are required to be addressed by nuclear power plant emergency plans. Section 3.2 discusses how these standards can be met by applying a graded approach to address guidance used in demonstrating compliance with emergency planning regulations, recognizing the significantly reduced risk to the public inherent in the HTGR design.

3. NGNP APPROACH TO HTGR EMERGENCY PLANNING

This section provides the rationale and identifies the information that will be used to establish and justify appropriate emergency planning for the HTGR, which generally results in simplification of the planning applied to LWRs. For the HTGR design, there is no credible licensing basis event resulting in severe core damage and associated large offsite radiological releases that warrants the need for large emergency planning zones and extensive offsite response plans. Key to simplifying emergency planning for the HTGR is identifying the considerations and bases that will be used to establish EPZ sizes.

The HTGR design places a greater emphasis on prevention through inherent and passive features to reduce the dependence on active systems thereby creating safety value without sacrificing defense-in-depth capability (INL 2009). Because of inherent design features of the HTGR, a significant reduction is achieved in the potential for an offsite radiological release. When we apply existing regulatory requirements to these technical details, we conclude that reliance on emergency planning can be reduced, when compared to an LWR.

Emergency planning requirements can be simplified by applying a graded approach to addressing guidance used in demonstrating compliance with existing regulatory requirements consistent with reduced risk associated with a reactor design with greater safety margins. Planning standards such as organization and staffing, facilities, emergency classification, assessment, prompt notification, onsite and offsite response, training, and periodic drills and exercises should be addressed in a manner consistent with the design and operating characteristics of the HTGR.

The NRC staff acknowledged in their draft Safety Evaluation Report (SER) for the Modular High Temperature Gas-cooled Reactor (NUREG-1338 issued in 1989) that, "In the past, the Commission has not required offsite emergency planning in those situations where the lower level PAGs were not expected to be exceeded." The NRC staff also commented that emergency planning requirements for advanced reactors should be based on the characteristics of plant design. At the time the draft SER was issued, the staff concluded that for designs that provide long times before significant radiation release, if sufficient time is available, prompt notification of offsite authorities will permit effective evacuation on an ad hoc basis. The staff's position was updated in the MHTGR Pre-application Safety Evaluation Report (PSER) (NUREG-1338 issued in 1995), which indicates that emergency preparedness is an integral part of the defense-in-depth philosophy and that the staff would delay issuing their position regarding emergency planning for the HTGR until at or before the design phase of the technology.

3.1 EPZ Sizing

Emergency planning is one level of the defense-in-depth philosophy as previously discussed in this paper and in the *Next Generation Nuclear Plant Defense-in-Depth Approach* paper (INL 2009). Establishing the size of the EPZ is critical to determining the appropriate level of emergency planning for the HTGR. As discussed in Section 2, there are several aspects of the HTGR design that are important to establishing the appropriate EPZ size. These considerations are:

- the potential for a severe core damage accident and the potential for a large offsite release of radioactive material
- how a large offsite release is prevented through application of defense-in-depth
- the characteristics of the limiting release applied to establishing the EPZ (e.g., content and magnitude of release, timing of release)
- how uncertainties and experience with the design and technology are taken into account.

This section presents the rationale and bases related directly to establishing the EPZ size and the impact of EPZ size on offsite emergency planning. While this section presents concepts, such as defense-in-depth, fuel design, and the functional containment for the HTGR, in a general manner, other NGNP papers on various topics provide detailed information regarding approaches being considered in the design of the HTGR. These papers include *Next Generation Nuclear Plant Defense-in-Depth Approach* (INL 2009), *Mechanistic Source Terms White Paper* (INL 2010), *NGNP Fuel Qualification White Paper* (INL 2010a), and *Licensing Basis Event Selection White Paper* (INL 2010b).

The methodology proposed for HTGR EPZ sizing will entail the following:

- Identify the applicable source term:
  - Determine the LBE scenarios
  - Determine the radiological release source terms for each accident scenario and the time from the start of the accident to time when a radiological release begins (see *Mechanistic Source Terms White Paper*)
  - Determine the timing of a significant radiological release
- Evaluate offsite dose consequences for each accident scenario and determine the distance at which the lower limit EPA PAGs are met
- Evaluate factors other than offsite dose consequences that would affect the establishment of the EPZ:
  - Evaluate any security, geographic, or travel route limitations
  - Evaluate whether a Design Basis Threat scenario can result in an accident with significant core damage and evaluate the timing of any postulated associated radiological release

3.1.1 Identifying the Applicable Source Term

The *Next Generation Nuclear Plant Defense-In-Depth Approach* white paper discusses the approach that will be used to assure that the principles of defense-in-depth are satisfied for the NGNP Project. The key to the defense-in-depth strategy for accident mitigation and limiting radiological release is the fuel design. The fuel characteristics, as well as several other significant features, are described in the paper as follows:

> - *The primary barrier to radionuclide transport for all the sources associated with the reactor spent, used, and new fuel is the multiple-coating feature of the Tristructural-Isotropic (TRISO) coated particles within the graphite fuel elements. This barrier is specifically designed to contain the radionuclide inventory during all envisioned normal, upset, and accident conditions.*
> - *The fuel has very large temperature margins to radioactivity release in normal and accident conditions.*
> - *The response times of the reactor during transients are very long (days as opposed to seconds or minutes).*
> - *The coated particle fuel, helium coolant, and graphite moderator are chemically and physically compatible under all conditions.*
> - *There is passive reactor shutdown capability because of a negative temperature coefficient under any transient involving under-cooling conditions.*

These features act independently to add multiple layers of defense to ensure fuel integrity during normal operation and all licensing basis events. With the fuel intact, radiological releases from the fuel and, ultimately, from the facility are limited only to those associated with allowable as-manufactured fuel defects or with limited, incremental, radiologically insignificant fuel particle coating degradation or failure during normal operations or resulting from accident sequences.

The individual fuel particle kernels and coatings, the fuel matrix and fuel element graphite, the helium pressure boundary (primary circuit), and a vented low-pressure reactor building constitute a functional containment that consists of multiple barriers that address defense-in-depth and will factor into the development of an appropriate emergency plan and EPZs. As an additional and final layer of defense, an emergency plan is also included as part of the defense-in-depth strategy. The emergency plan will describe protective actions for the public to mitigate the consequences of a radiological release.

As discussed in the *Mechanistic Source Terms White Paper* and the *NGNP Fuel Qualification White Paper*, based on previous analyses of modular HTGRs, there are no credible accident scenarios that involve severe core damage with a large early radiological release. This is because of the high integrity of the fuel and the low power density, thermal inertia resulting from use of large graphite masses in the core design, and many other features discussed in the *Mechanistic Source Terms White Paper.*

Dose calculations will be performed to demonstrate that radiological releases from a licensing basis event will not exceed the lower level EPA PAGs: 1 rem TEDE or 5 rem CDE to the thyroid at the EAB. Table 4-2 of the *Mechanistic Source Terms White Paper* provides the following classes of radionuclides of primary interest for HTGR design:

Radionuclide Class	Key Nuclide
Tritium	H-3
Noble gases	Xe-133
Halogens	I-131
Alkali metals	Cs-137
Tellurium group	Te-132
Alkaline earths	Sr-90
Noble metals	Ag-110m
Lanthanides	La-140
Actinides	Pu-239

3.1.1.1 *Severe Accident Analysis*

The *Licensing Basis Events Selection White Paper* outlines the relevant regulatory policy and guidance for the spectrum of LBEs to be considered, defines licensing issues associated with LBE definition, describes the NGNP methodology for the selection of the LBEs, and sets forth certain facts for review and discussion to facilitate an effective submittal leading to an HTGR COLA under 10 CFR Part 52.

LBEs cover a comprehensive spectrum of events from normal operation to rare, off-normal events. There are three categories of LBEs:

- Anticipated Operational Occurrences (AOOs), which encompass planned and anticipated events. The doses from AOOs are required to meet normal operation public dose requirements. AOOs are utilized to set operating limits for normal operation modes and states. AOOs include event sequences with mean frequencies greater than 10^{-2} per plant-year. Acceptable dose limits for AOOs are addressed in 10 CFR Part 20: 100 mrem TEDE mechanistically modeled and realistically calculated at the EAB.

- DBEs which encompass unplanned, off-normal events not expected in a single plant's lifetime, but which might occur in the lifetime 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 safety-related SSCs during accidents. DBEs include event sequences with mean frequencies less than 10^{-2} per plant-year and greater than 10^{-4} per plant-year. Acceptable dose limits for DBEs are addressed in 10 CFR §50.34: 25 rem TEDE mechanistically modeled and conservatively calculated at the EAB.
- Beyond Design Basis Events (BDBEs), which are rare, off-normal events of lower frequency than DBEs. BDBEs are evaluated to ensure that they do not pose an unacceptable risk to the public. BDBEs include event sequences with mean frequencies less than 10^{-4} per plant-year and greater than 5×10^{-7} per plant-year. Acceptable dose limits for BDBEs are addressed in NRC Safety Goal QHOs mechanistically and realistically calculated at 1 mile (1.6 km) and 10 miles (16 km) from the plant.

The technical analysis that would be used to size the EPZs will be based on the potential offsite dose consequences from a spectrum of credible LBE accident scenarios. This resulting analysis will inherently consider the probability for the possible accidents and the amount of time from the start of each accident to the release of radioactive material. This will be consistent with the Commission's defense-in-depth safety philosophy.

Fuel integrity and functional containment are described in the *Mechanistic Source Terms White Paper* and the *NGNP Fuel Qualification White Paper*. These papers provide the basis for excluding severe core damage in any accident scenario. Technical justifications for maintaining fuel integrity include an evaluation of a spectrum of accident scenarios (see *NGNP Fuel Qualification White Paper*). Eliminating the possibility of a large fission product release provides the technical justification for small radiological release source terms during licensing basis events. A small radiological release source term and functional containment requirements provide the inputs needed to illustrate minimal offsite dose consequences and ultimately the correct EPZ sizes for the HTGR design.

3.1.1.2 *Relationship to Functional Containment*

As described in Section 3.1.1, the fuel integrity is the key parameter for accident mitigation and limiting any radiological releases as a result of plant transients or accident scenarios. As stated in the *Next Generation Nuclear Plant Defense-In-Depth Approach* paper:

> *For HTGR designs, including the NGNP, no appreciable core damage is expected to occur for any DBE (Design Basis Event) or BDBE (Beyond Design Basis Event).*

With no significant core damage, any radiological releases from the HTGR would be limited to those associated with allowable as-manufactured fuel defects or limited, incremental fuel degradation during normal operation and LBEs. This design parameter cannot be emphasized enough because it limits the offsite consequences of any accident scenario. It also allows for a different plant design concept that relies less on other plant structures, such as a containment structure, to contain the radiological inventory. Section 4.4.3 of the *Mechanistic Source Terms White Paper* discusses functional containment for the HTGR:

> *The multiple barriers to fission product release and radionuclide transport described in this paper form a functional containment limiting the release of radionuclides to the environment. This functional containment is comprised of the kernel and coatings of the TRISO coated fuel particles, the fuel matrix and fuel element graphite, the primary circuit, and the reactor building. Each of these barriers contributes to limiting the release of radionuclides to the environment to meet the NGNP Project top level radiological criteria. The contribution of each of the barriers in limiting the transport and release of radionuclides to the*

environment is calculated for each postulated event depending on the response of the reactor to the event.

3.1.2 Calculation Methodology for Offsite Dose Consequences

The radiological basis for determining the appropriate EPZ for the HTGR is from dose assessments that evaluate the consequences from the most limiting licensing basis event scenarios. These dose assessments will be used to determine the distance at which the EPA PAG doses are met. The results of the dose assessments will be a bounding distance that will be used as a basis for establishing the appropriate EPZ boundaries. The bounding distances will not necessarily set the EPZ boundary, but they will significantly inform the setting of the boundary.

The EPA PAG plume exposure doses that must be met are 1 rem TEDE, and 5 rem CDE to the thyroid, which are the lower thresholds for taking protective actions. Dose assessments will be conducted to determine the distances at which these guideline values can be met.

The dose assessment can be completed by using industry standard dose consequence modeling software with dose conversion factors consistent with those used in Federal Guidance Reports 11 and 12 (EPA 1988; EPA 1993). Data inputs include:

- Radiological release source terms consistent with the reactor size and the most limiting LBE scenarios
- X/Q values
- Release height consistent with accident assumptions and the facility design
- Radiological release duration.

Fundamental to the dose assessment is the development of a reasonable and technically defensible radiological release source term so that a radionuclide specific release rate can be calculated. Of particular importance is the iodine source term because of its impact on the thyroid dose limits. Based on previous HTGR safety analyses, the thyroid dose is expected to be limiting. Also, source terms for particulate radionuclides such as cesium are important, as they will dominate the ingestion pathway doses.

3.1.2.1 Ingestion Pathway EPZ Dose Calculations

As discussed in Section 2, protective actions within the ingestion pathway EPZ are based on the EPA PAGs for the intermediate phase following an accident at a nuclear power plant. Radiation exposure levels are provided for "preventive" PAGs, but the use of sophisticated pathway analysis is required. Computer models, accepted by the NRC for nuclear plant licensing, would be used to provide the necessary dose assessments.

3.1.3 Factors Other Than Offsite Dose Consequences that Influence EPZ Size

This paper previously discussed other HTGR design features, such as source term and release characteristics, fuel integrity, functional containment, and timing of release that influence the EPZ size and offsite emergency planning. Other factors influencing the EPZ size include:

- Co-location at an existing nuclear power plant – the size of the EPZ would be influenced by the EPZ requirements for the other plant.
- Co-location of multiple HTGRs at a site – the size of the EPZ would be influenced by the EPZ configuration (i.e., centerline) for each of the other plants.
- Control of access to the site – an HTGR sited on a secure reservation would influence the offsite emergency planning requirements.

- Co-location with an industrial facility – influenced by regulatory requirements and existing emergency programs for the industrial facility.
- Other local conditions such as demography, topography, land characteristics, access routes, and local jurisdictional boundaries.

3.1.3.1 Other Factors that Impact the EAB for Potential NGNP Sites

The EAB should consider not only compliance with the PAGs, but also the unique characteristics of the site selected for the HTGR. These characteristics include security considerations, potential effects on the reactor operations from an accident associated with the nearby industrial facility, and demographic information.

A reactor licensee is required by 10 CFR 100.21(a) to designate an exclusion area and to have authority to determine all activities within that area, including removal of personnel and property. In selecting a site for a nuclear power station, it is necessary to provide for an exclusion area in which the applicant has such authority. According to RG 4.7, transportation corridors such as highways, railroads, and waterways are permitted to traverse the exclusion area, provided (1) these are not so close to the facility as to interfere with normal operation of the facility, and (2) appropriate and effective arrangements are made to control traffic on the highway, railroad, or waterway in case of emergency to protect the public health and safety.

As stated in 10 CFR 100.21(g), "Physical characteristics unique to the proposed site that could pose a significant impediment to the development of emergency plans must be identified." An examination and evaluation of the site and its vicinity, including the population distribution and transportation routes, should be conducted to determine whether there are any characteristics that would pose a significant impediment to taking protective actions to protect the public in the event of emergency.

Accidents at present or projected nearby industrial facilities may affect the safety of a nuclear power station (see Section 2.2 of RG 1.70) (NRC 1978a). According to 10 CFR 100.21(e):

> *Potential hazards associated with nearby transportation routes, industrial and military facilities must be evaluated and site parameters established such that potential hazards from such routes and facilities will pose no undue risk to the type of facility proposed to be located at the site.*

Accidents at nearby industrial facilities such as chemical plants, refineries, mining and quarrying operations, oil or gas wells, or gas and petroleum product storage installations may produce missiles, shock waves, flammable vapor clouds, toxic chemicals, or incendiary fragments. These may affect the station itself or the station operators in a way that jeopardizes the safety of the station. If a preliminary evaluation of potential accidents at these facilities indicates that the potential hazards from shock waves and missiles approach or exceed those of the design basis tornado for the region, or potential hazards such as flammable vapor clouds, toxic chemicals, or incendiary fragments exist, the suitability of the site should be determined by detailed evaluation of the potential hazard.

According to RG 4.7, based on experience and analysis, the NRC staff has found that a distance of about 110 meters (360 feet) to any vital structure or vital equipment would provide sufficient space to satisfy security measures of 10 CFR 73.55 (e.g., protected area barriers, detection equipment, isolation zones, vehicle barriers). If the distance to a vital structure or vital equipment is less than about 110 meters (360 feet), special measures or analyses may be needed to show that adequate security plans can be developed. The proposed EAB for the HTGR would meet this guidance.

The acceptability of a site depends on establishing that (1) an accident at a nearby industrial, military, or transportation facility will not result in radiological consequences that exceed the dose guideline in 10 CFR 50.34(a)(1), or (2) the accident poses no undue risk because it is sufficiently unlikely to occur

(less than about 10^{-7} per year), or (3) the nuclear power station can be designed so its safety will not be affected by the accident.

In SECY 2009-0007, *Proposed Rule Related to Enhancements to Emergency Preparedness Regulations (10 CFR Part 50) (RIN 3150-AI10)* (NRC 2009a), the NRC staff discussed their comprehensive review of requirements and proposed a number of revisions to emergency planning requirements for security based events. SECY 2009-0007 outlined a series of NRC orders and policy papers issued since 9/11 that addressed coordination measures between emergency planning and security areas. The proposed rule changes, while not specific to the topic of EPZ sizing, did address aspects related to the adequacy of onsite emergency response capabilities (as well as offsite coordination). Such considerations have potential implications for co-locating nuclear heat generation and application facilities (as with the HTGR). The NRC Commissioners approved the staff's recommendation for publishing the proposed changes in the Federal Register. Subsequently, the proposed rule was published requesting public comments (74 FR 23254, May 18, 2009). The comment period, initially set to close August 3, 2009, was extended to October 19, 2009 (74 FR 27724, June 11, 2009). The staff will submit the draft final rule to the Commission in late 2010. Following Commission approval, the final rule will be published in the *Federal Register*. Significant changes promulgated in NRC's final requirements and guidance from the proposed rule would need to be evaluated for impact on the HTGR.

3.1.4 Regulatory Basis for EPZ Sizing

As noted in Section 2.1.1, 10 CFR 50.33(g) and 50.47(c)(2) provide for the EPZs for gas-cooled reactors to be determined on a case-by-case basis. This paper identifies information needed to support the case for the HTGR EPZ sizes.

It is expected that the selected license applicant will develop a Technical Report that implements the approach for establishing the EPZ sizes and provides supporting technical bases for submittal to the NRC. The Technical Report will discuss the rationale for selecting which LBEs are considered for emergency planning and how the increased safety provided through a greater emphasis on inherent and passive features can reduce the reliance on emergency planning, when compared to an LWR.

The Technical Report would be expected to discuss the technical approach used to establish the EPZ size and analyze potential offsite dose consequences from a spectrum of credible accident scenarios, taking into account the probability for the possible accidents, the radioactive source term, and the amount of time from the start of each accident to the release of radioactive material. This approach will be consistent with 10 CFR 50.47 as well as the Commission's positions in SECY 97-0020, SECY 03-0047, and SECY 10-0034.

3.2 Graded Approach to Emergency Plans for the HTGR

As previously mentioned in this paper, emergency planning requirements can be simplified by applying a graded approach to addressing guidance used in demonstrating compliance with existing regulatory requirements consistent with reduced risk associated with a reactor design with greater safety margins. This section discusses how the regulatory standards in 10 CFR 50.47(b), such as organization and staffing, facilities, emergency classification, assessment, prompt notification, onsite and offsite response, training, and periodic drills and exercises can be addressed in a manner consistent with the design and operating characteristics of the HTGR.

3.2.1 Emergency Planning Requirements with Corresponding EPZ Sizing

10 CFR 50.47(b) provides 16 standards that must be addressed in a nuclear power plant emergency plan. Detailed requirements on these standards are provided in Appendix E to 10 CFR 50. Implementation guidance is provided in NUREG-0654. The regulatory guidance can be addressed on a graded approach consistent with the reduced risk associated with a HTGR design with significantly enhanced safety

margin. The smaller the plume exposure EPZ, the less complex the resulting emergency plans. Sections 3.2.3 and 3.2.4 provide detailed discussions on the impact of EPZ size on offsite emergency planning. Table 3-1 summarizes an analysis of the effects of HTGR design characteristics on overall emergency planning relative to the 16 standards of 10 CFR 50.47(b). The considerations identified in this table are relative to requirements that exist in current emergency plans for LWRs. It should be noted that any offsite emergency plans developed for the HTGR would likely be developed as a Nuclear/Radiological Incident Annex in the offsite emergency plans if one does not already exist for another radiological hazard.

Table 3-1. Consideration of 10 CFR 50.47 Emergency Planning Standards for the HTGR.

Planning Standard	HTGR Considerations
§50.47(b)(1): Assignment of responsibility (organizational control) Primary responsibilities for emergency response by the nuclear facility licensee and by state and local organizations within the EPZs have been assigned, the emergency responsibilities of the various supporting organizations have been specifically established, and each principal response organization has staff to respond and to augment its initial response on a continuous basis.	Licensee emergency response organizational structure is simplified. Offsite emergency response organizational structure is simplified (fewer jurisdictions due to smaller impact zones).
§50.47(b)(2): Onsite emergency organization On-shift facility licensee responsibilities for emergency response are unambiguously defined, adequate staffing to provide initial facility accident response in key functional areas is maintained at all times, timely augmentation of response capabilities is available, and the interfaces among various onsite response activities and offsite support and response activities are specified.	On-shift staffing based on reactor design. Augmented staffing needs are fewer and required response times are increased.
§50.47(b)(3): Emergency response support and resources Arrangements for requesting and effectively using assistance resources have been made, arrangements to accommodate State and local staff at the licensee's near-site Emergency Operations Facility have been made, and other organizations capable of augmenting the planned response have been identified.	Offsite fire, ambulance commensurate with other industrial facilities.
§50.47(b)(4): Emergency classification system A standard emergency classification and action level scheme, the bases of which include facility system and effluent parameters, is in use by the nuclear facility licensee, and State and local response plans call for reliance on information provided by facility licensees for determinations of minimum initial offsite response measures.	Four levels remain intact, unless General Emergency conditions cannot be met.
§50.47(b)(5): Notification methods and procedures Procedures have been established for notification, by the licensee, of State and local response organizations and for notification of emergency personnel by all organizations; the content of initial and follow-up messages to response organizations and the public has been established; and means to provide early notification and clear instruction to the	Number of participating agencies/jurisdictions is driven by EPZ size.

Table 3-1. (continued).

populace within the plume exposure pathway Emergency Planning Zone have been established.	
§50.47(b)(6): Emergency communications Provisions exist for prompt communications among principal response organizations to emergency personnel and to the public.	Need for prompt notification and supporting systems is reduced because of the absence of a significant release of radioactive material.
§50.47(b)(7): Public education and information Information is made available to the public on a periodic basis on how they will be notified and what their initial actions should be in an emergency (e.g., listening to a local broadcast station and remaining indoors), the principal points of contact with the news media for dissemination of information during an emergency (including the physical location or locations) are established in advance, and procedures for coordinated dissemination of information to the public are established.	Information dissemination needs are reduced due to smaller plume exposure EPZ.
§50.47(b)(8): Emergency facilities and equipment Adequate emergency facilities and equipment to support the emergency response are provided and maintained.	Potential to consolidate Technical Support Center (TSC) and Emergency Operations Facility (EOF) into a single facility due to lessened and more reasonable timing of emergency response actions; or combine TSC and EOF with existing co-located facilities. Lessened emergency response equipment needs.
§50.47(b)(9): Accident assessment Adequate methods, systems, and equipment for assessing and monitoring actual or potential offsite consequences of a radiological emergency condition are in use.	Still required.
§50.47(b)(10): Protective response A range of protective actions has been developed for the plume exposure pathway EPZ for emergency workers and the public. In developing this range of actions, consideration has been given to evacuation, sheltering, and, as a supplement to these, the prophylactic use of potassium iodide, as appropriate. Guidelines for the choice of protective actions during an emergency, consistent with federal guidance, are developed and in place, and protective actions for the ingestion exposure pathway EPZ appropriate to the locale have been developed.	Limited offsite protective actions due to smaller plume exposure EPZ.
§50.47(b)(11): Radiological exposure control 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.	Still required onsite. Fewer offsite requirements due to smaller plume exposure EPZ.
§50.47(b)(12): Medical and public health support	Still required onsite.

Table 3-1. (continued).

Arrangements are made for medical services for contaminated injured individuals.	Offsite support will be less due to smaller impact zone and consequently fewer jurisdictions.
§50.47(b)(13): Recovery and reentry planning and post-accident operations General plans for recovery and reentry are developed.	General plans for recovery and reentry commensurate with design.
§50.47(b)(14): Exercises and drills Periodic exercises are (will be) conducted to evaluate major portions of emergency response capabilities, periodic drills are (will be) conducted to develop and maintain key skills, and deficiencies identified as a result of exercises or drills are (will be) corrected.	More limited in scope for onsite and participating offsite agencies/jurisdictions due to smaller EPZ.
§50.47(b)(15) Radiological emergency response training Radiological emergency response training is provided to those who may be called on to assist in an emergency.	Fewer onsite requirements. Offsite limited to fire/rescue/medical and affected jurisdiction.
§50.47(b)(16): Responsibilities for emergency planning Responsibilities for plan development and review and for distribution of emergency plans are established, and planners are properly trained.	Less onsite effort required to maintain plans and program. Offsite integrated into all-hazards planning, instead of unique REP plans as discussed in Appendix A.

3.2.2 Emergency Action Levels/Initiating Conditions for LWRs

Another aspect of emergency planning that will need to be considered for the HTGR is the emergency classification scheme. The four standard classes of emergency provided in 10 CFR 50 Appendix E would apply: Notification of Unusual Event, Alert, Site Area Emergency, and General Emergency. The Nuclear Energy Institute (NEI) has developed two guidance documents providing the methodology for developing ICs and EALs for the current operating LWRs (NEI 99-01) and advanced (passive) LWRs (NEI 07-01).

ICs and EALs for LWRs focus on the three fission product barriers: fuel cladding, reactor coolant system, and containment. These barriers are designed to prevent radiological release from the plant during accident scenarios. These barriers work together so that it would take a loss of all three for radiological release amounts to be significant.

The fission product barriers for the HTGR are significantly different from those of traditional LWRs, particularly with respect to their ability to withstand breaches. In fact the most significant barrier, the fuel, is designed such that "no appreciable core damage is expected to occur for any DBE or BDBE " (INL 2009). This design feature is essential, because without core damage, the amount of radiological release from the HTGR is limited to that associated with allowable as-manufactures fuel defects and limited incremental degradation of fuel particle coatings during normal operation and LBEs (INL 2010). The inability to transport the radionuclide inventory out of the fuel virtually eliminates the possibility of ever reaching a General Emergency based on plant conditions.

A review of the NEI ICs and EALs indicated that most would not apply to the HTGR. However the EAL category called, "Hazards and Other Conditions Affecting Plant Safety," would apply to the HTGR. Although a scenario involving plant conditions warranting a General Emergency declaration may not be credible, IC HG1, "HOSTILE ACTION resulting in loss of physical control of the facility," is a credible event and would result in declaring a General Emergency, which requires public protective actions in the plume exposure EPZ. The other IC that would result in a General Emergency is HG2, "Other conditions exist which in the judgment of the Emergency Director warrant declaration of a General Emergency." A

more thorough analysis based on plant design is warranted to determine the correct set of ICs and EALs for the HTGR. The EAL methodology will be provided at the time the COLA is submitted.

3.2.3 Relationship to Local Emergency Response Needs and Capabilities

FEMA regulations (44 CFR 350) and NRC regulations [10 CFR 50.47(b) and Appendix E of 10 CFR 50] specify standards that must be met regarding the content of onsite and state and local emergency response plans. NUREG-0654 was issued to provide guidance and evaluation criteria as a basis for NRC licensees and state and local governments in developing radiological emergency response plans and to improve existing emergency preparedness following the Three Mile Island accident. NUREG-0654 contains 16 planning standards (see Table 3-1) and 109 evaluation criteria applicable to offsite emergency response plans and identifies capabilities and functions to be included in those plans. The individual evaluation criteria address a broad range of responsibilities and capabilities, including technical activities such as radiological monitoring and instrumentation, and more general aspects of emergency response such as communications, public notification, and evacuation. Licensees and state and local response organizations must demonstrate that they have plans in place that provide a reasonable assurance that adequate protective measures can and will be taken to protect public health and safety in the event of an emergency at a nuclear power plant.

FEMA and NRC regulations expect state and local cooperation in the planning effort, but allow a licensee or applicant to present a comprehensive emergency plan that addresses state and local requirements in the event offsite officials choose not to participate. Before a combined license is issued, the NRC must find, in consultation with FEMA, that the emergency plans submitted in support of a COLA meet the existing emergency planning standards and requirements of 44 CFR 350, 10 CFR 50.47, and Appendix E to 10 CFR 50. By applying the 16 planning standards and associated evaluation criteria identified in NUREG-0654, the NRC evaluates the adequacy of the onsite emergency plans and capabilities, and FEMA evaluates the adequacy of the offsite emergency plans and capabilities.

Currently, state and local government entities that are wholly or partially within the plume exposure EPZ have the overall responsibility to implement the appropriate protective actions, such as evacuation or sheltering in place, for the public during a nuclear power plant radiological emergency, based on recommendations from the licensee. Additionally, they are responsible for prompt notification of the EPZ population, offsite dose assessment and dose projections, and offsite environmental monitoring. Depending on the HTGR's proximity to jurisdictional boundaries, a small plume exposure EPZ would limit the number of state and local government entities that are wholly or partially within the EPZ and would, therefore, limit the number of response agencies involved in the required planning efforts.

For example, at a radius of 400 m, which is equivalent to less than two-tenths of a square mile in area, the permanent and transient populations within the EPZ are likely to be minimal, and the resources needed and requirements for offsite emergency planning for the protection of the public would be minimal in relation to the offsite planning developed for currently operating LWRs. Co-located workers at an adjoining industrial facility inside the EAB would be included in site emergency plans. Although an offsite emergency plan for the ingestion pathway EPZ would still be required, these plans are largely ad hoc in basis. Offsite planning would be simplified with respect to detailed evacuation planning, provisions for early notification, or provisions for training and exercising within the plume exposure pathway EPZ. These aspects of emergency planning could take place utilizing existing state and local emergency plans developed to address other hazards.

The time between accident initiation and release of radioactive materials is critical to the discussion of local emergency response needs and capabilities. Because of the very low probability of a release of radioactive material as well as the longer time period between accident initiation and release, reasonably timely notification of offsite authorities will permit effective protective actions without the level of planning currently required for LWRs (NRC 1989). Any protective actions, such as evacuation or sheltering in place, would involve the use of current state and local government sheltering and evacuation

plans for responding to natural and technological or industrial hazards. Additionally, prompt public alert and notification could be accomplished on an ad hoc basis using existing state and local government methods already in place for response to existing hazards. The existing state and local emergency plans for other hazards would be bolstered by the minimum additional offsite planning associated with an HTGR (NRC 1989).

Establishment of a 400 m plume exposure EPZ will not relieve the licensee or the offsite agencies that are located wholly or partially within the EPZ of the need to address the planning standards and evaluation criteria provided in NUREG-0654. However, the unique characteristics of the HTGR must be considered by the NRC and FEMA during review and evaluation of emergency plans. As a result, the 16 planning standards and associated evaluation criteria would be applied in a graded approach, consistent with the determined level of risk at the facility.

According to the Section 13.1.5 of the draft SER on the MHTGR (NUREG-1338), the dose projection and assessment requirements in offsite plans for the plume exposure pathway EPZ would be eliminated because the much longer times available would permit an independent confirmation of the licensee's projections by state and federal organizations. Offsite environmental monitoring requirements for the plume exposure pathway EPZ would be eliminated for the same reasons; that is, the licensee's monitoring provisions would suffice until others could be put in place. However, as the HTGR design progresses, design detail or administrative controls will be required to demonstrate that the necessary equipment could be made available within a reasonable period and that personnel would be adequately trained for its use. For the ingestion pathway EPZ, requirements for dose projections and assessment and environmental monitoring would remain. (NRC 1989)

The absence of significant radiological releases minimizes the potential for members of the public becoming contaminated or receiving radiation doses requiring medical intervention. Requirements in offsite plans related to arrangements for medical services for contaminated or injured members of the general public may not be necessary, or could be reduced because of the lower releases.

Special training for response in the plume exposure pathway EPZ would not be required for offsite plans for the HTGR because general training in emergency response that is part of state and local governments' response to other hazards would encompass response to radiological events, such as transportation accidents or terrorist attacks. The exercise requirement for state and local governments for the plume exposure pathway EPZ would also be eliminated; however, the exercise requirement for state and local governments for the ingestion pathway EPZ would be retained. The current requirement for training and exercises for offsite emergency workers who would respond on site, such as police, fire, and rescue personnel, is traditionally part of the onsite plan. This would remain a requirement for the onsite plan. (NRC 1989)

In summary, simply considering the total land area of a smaller EPZ, local emergency response requirements are dramatically reduced. The smaller EPZ inherently results in smaller populations and fewer jurisdictions that could be affected during an emergency. Variations in topography and land characteristics are reduced. The roadway network is much less complex, and access routes would be limited in number. Accordingly, the local emergency response requirements are significantly reduced and can be accommodated within existing emergency response plans in place and used for responding to natural and technological hazards, with the addition of a nuclear/radiological incident response annex if needed. Feedback obtained from the NRC on the adequacy of the approach to establishing the size of the EPZs described in this paper will form the basis for graded approach the NGNP Project considers appropriate for the onsite and offsite emergency preparedness for the HTGR.

3.2.4 Assessment of Interfaces with, and Requirements of, Coordinating Agencies (e.g., within the National Response Framework)

Emergency plans must be coordinated among all levels of government to ensure an effective response. The goal is to ensure the effectiveness of combined federal and state, territorial, tribal, and local operations through integration and synchronization. This integration is achieved through FEMA's Comprehensive Preparedness Guide on *Developing and Maintaining State, Territorial, Tribal, and Local Government Emergency Plans* (CPG-101) (FEMA 2009) and the National Response Framework (NRF)(DHS 2008). CPG-101 provides emergency managers and other emergency services personnel with recommendations on how to address the entire planning process. It also encourages emergency managers to follow a process that addresses all of the hazards that threaten their jurisdiction through plans connected to a single, integrated emergency operations plan. The NRF provides for a coordinated response from all levels of government, to all types of hazards regardless of their origin. The NRF contains incident annexes that address unique aspects of response to several broad incident categories, including a nuclear/radiological incident.

Appendix A provides a detailed discussion of the assessment of interfaces with, and requirements of, coordinating agencies within the NRF (DHS 2008) and illustrates how the 16 planning standards and associated evaluation criteria presented in NUREG-0654 can be integrated into existing state and local emergency operations plans based on the NRF. Offsite emergency plans developed for the HTGR would be developed as a Nuclear/Radiological Incident Annex in the offsite emergency plans if one does not already exist for another radiological hazard associated with the selected site.

3.2.4.1 Engaging with Federal, State, and Local Authorities

The emergency planning approach taken for the HTGR needs to be communicated with the affected federal, state, and local agencies to establish an understanding of the emergency planning requirements between agencies and the licensee. As a result, early, frequent, and consistent communications are crucial in the emergency planning process. The size of the HTGR EPZ and the anticipated roles and responsibilities of the offsite agencies located within the EPZ will necessitate significant communications with FEMA and the NRC.

Likewise, engagement of the state and local agencies within the EPZ should take place as early as possible to ensure cooperation in the emergency planning process. The strategy in engaging the state and local authorities will depend on the location of the HTGR site and whether the emergency plans of state and local governments currently address nuclear power plants. If the HTGR is located within a state or locality that currently plans for a nuclear power plant emergency, communications will focus on the differences between existing LWR technology and the HTGR and the anticipated differences in the roles and responsibilities of the offsite agencies. If the HTGR is located within a state or locality that does not currently plan for a nuclear power plant emergency, communications will focus on development of the emergency plans and the roles and responsibilities of the offsite agencies.

3.3 Licensing Document Structure and Regulatory Impacts

The NGNP Project licensing strategy is focused on submitting a COLA in accordance with 10 CFR 52.71. An approach for establishing the emergency planning requirements for the COL are discussed previously in this paper, and a high level discussion of the major regulatory driver for the COL emergency plan (planning standards in 10 CFR 50.47) is provided. This white paper presents the case for applying a graded approach to addressing guidance used in demonstrating compliance with the regulatory requirements for the content of a COL emergency plan.

3.3.1 Proposed Changes to Regulatory Guidance Documents or Requirements

This section of the white paper discusses any changes proposed to NRC regulations or guidance to accommodate the proposed HTGR emergency planning strategy. No such changes are necessary to

support establishing the appropriate EPZs for the HTGR. Early in the paper, NRC proposed changes to their emergency planning regulations and guidance were summarized, noting that the current regulatory structure is based on LWR technology.

Of related interest to emergency planning are new security requirements or proposed rules that could impact the HTGR emergency plan. While it is acknowledged that work is ongoing in this area, the requirements continue to evolve and are expected to continue evolving in the future. Therefore, the NGNP Project will monitor security regulatory and guidance changes and consider how future changes impact the HTGR emergency plan.

3.3.2 Potential Impact of Other Regulatory Initiatives

As noted previously, NRC staff is working on an updated realistic evaluation of potential severe reactor accidents and their offsite consequences, known as "state-of-the-art reactor consequence analysis" (SOARCA). The NRC recently completed the preliminary analysis of a boiling water reactor (Peach Bottom Atomic Power Station) and a pressurized water reactor (Surry Power Station), the first two pilot plants of the SOARCA project. The NRC is using the improved knowledge and the technological advances gained over the past 25 years to develop a realistic consequence analysis that considers the risk, design features, improvements in mitigative measures, and emergency response capabilities to determine the potential consequences from a severe accident and the potential health effects on the public. Of direct interest to establishing the EPZ size for the HTGR is the methodology presented in SECY 08-0029, *State-of-the-Art Reactor Consequence Analyses – Reporting Offsite Health Consequences*, which may influence the dose calculation methodology ultimately implemented by NGNP.

The EPA has indicated that the EPA PAG Manual will be revised in the future. However, the latest information from the EPA website (http://www.epa.gov/rpdweb00/rert/pags.html#status) provided the following status (as of June 2010) (EPA 2010):

> *The PAG Manual is an important science-based guideline that addresses emergency action levels for radiation exposure. Draft revisions were approved by the former Deputy Administrator shortly before the inauguration. The new team at EPA wishes to review the PAGs revisions before proceeding with a notice of availability and public comment.*

After the manual is revised, any changes will be evaluated and considered in the dose calculation methodology for establishing the EPZ sizes.

3.4 Summary of Emergency Planning Insights for the NGNP Project

The regulatory foundation for emergency planning was reviewed in Section 2 of this paper. 10 CFR 50.33(g) provides that the EPZ for a gas-cooled reactor may be determined on a case-by-case basis. Various guidance documents and precedents for establishing EPZ sizes are discussed. Dose calculations and the source terms and release characteristics for licensing basis events will play critical roles in establishing the EPZ size. This paper also examines the 16 emergency planning standards promulgated in 10 CFR 50.47 and how both onsite and offsite emergency planning may be affected by establishing a plume exposure EPZ smaller than that required of LWRs. This paper described the methodology to establish the appropriate EPZ size for the HTGR. The actual EPZ size for any specific site will be developed using this methodology and documented in a Technical Report, which will be submitted to the NRC by the future license applicant for review and approval.

4. ISSUES FOR PRE-APPLICATION RESOLUTION

4.1 NRC Discussion Topics

Section 1.3 of this paper introduced a set of issues to be addressed in this paper. The issues addressed in this paper are presented in terms of justification for an approach to emergency planning requirements that is consistent with policy, engineering, and programmatic considerations that reflect the design and operating characteristics of the HTGR envisioned by the NGNP Project. The issues are addressed in terms of the following statements:

- It is justifiable and desirable to appropriately size the plume and ingestion pathway EPZs and potentially simplify emergency planning requirements for reactors that are designed with greater safety margins. For the HTGR design, there is no credible licensing basis event resulting in severe core damage and associated large offsite radiological releases that would justify the need for very large emergency planning zones and extensive offsite response plans.
- The HTGR design places a greater emphasis on prevention through inherent and passive features to reduce the dependence on active systems thereby creating safety value without sacrificing defense-in-depth capability (INL 2009). Because of inherent design features of the HTGR, a significant reduction is achieved in the potential for an offsite radiological release. When we apply existing regulatory requirements to these technical details, we conclude that reliance on emergency planning can be reduced, when compared to an LWR.
- Emergency planning requirements can be simplified, when compared to current emergency plans for LWRs, by applying a graded approach to addressing guidance used in demonstrating compliance with existing regulatory requirements consistent with reduced risk associated with a reactor design with greater safety margins. Planning standards such as organization and staffing, facilities, emergency classification, assessment, prompt notification, onsite and offsite response, training, and periodic drills and exercises should be addressed in a manner consistent with the design and operating characteristics of the HTGR.

4.2 Outcome Objectives

The objective of this paper is to solicit NRC feedback and agreement on the appropriate information related to EPZ sizing sufficient to support NGNP Project licensing. Relevant elements of the NGNP Project focus and white paper development, including fuel qualification, mechanistic source term, functional containment, and defense-in-depth, support the strategy for a graded approach to addressing guidance used in demonstrating compliance with emergency planning requirements outlined in this paper. The NGNP Project is seeking NRC's general concurrences and/or comments on the overall approach to establish the EPZ sizes for the HTGR and to obtain feedback from the NRC on any issues that have the potential to significantly impact the effort and schedule to prepare a COLA for a first-of-a-kind HTGR plant under the NGNP Project. The following are specific areas where agreement on the NGNP Project approach to establish the EPZ sizes is being sought:

1. Application of the defense-in-depth methodology developed for the HTGR provides a foundation for technical justification for EPZ sizing because of a resulting set of conservative design features that, when combined with inherent reactor characteristics, passive design features, and active systems, are designed to (1) prevent transients and accidents, (2) ensure the performance of safety functions, (3) prevent the release of radioactive material, and (4) mitigate the consequences of accidents.
2. The design and operating characteristics of the HTGR support the development of emergency planning requirements that are consistent with the greater safety margins and reduced risk associated with the reactor design.

- The mechanistic source term approach, and radionuclide inventories elsewhere in the facility that are determined during source term analysis, can be used to establish EPZ sizes. The mechanistic approach to source term development establishes the technical basis and takes appropriate credit for the radionuclide retention capabilities of each of the multiple barriers to radionuclide transport to the environment consistent with the HTGR safety design approach.
- A significant release of radioactive material is prevented through fuel design that consists of a multiple-coating-layer system that has been engineered to retain the fission products generated by fission of the nuclear material in the kernel during normal operation and all licensing basis events over the design lifetime of the fuel. Although plant safety depends on many factors, the TRISO-coated fuel is particularly critical to the safe operation of the reactor because the fuel particles are the primary (but not the only) barrier to fission-product release in HTGRs.

3. Confirmation that EPZ sizing should be determined, in part, from offsite dose consequences of LBEs and design basis threats to determine the distance at which the lower limit EPA PAGs are met for each event scenario.

4. Concurrence that technical justification for the appropriate EPZ size can be based on the absence of a significant radiological release during an accident thus potentially allowing offsite emergency response to be accommodated, in part, through existing all-hazards plans.

5. Compliance with the emergency planning requirements in 10 CFR 50 can be applied on a graded approach, when compared to current emergency plans for LWRs, that allows for site and offsite emergency plans to be developed commensurate with the HTGR design. For example:

   a. Simplification of onsite and offsite emergency response organization
   b. Potential reduction of on-shift staffing requirements
   c. Offsite fire/rescue and medical facility capabilities consistent with existing industrial hazard plans (with the addition of a nuclear/radiological incident annex if needed)
   d. Potential reduction in number of participating agencies and jurisdictions
   e. Potential reduction in the need for prompt notification
   f. Consolidation and simplification of emergency response facilities
   g. Offsite response and protective action strategy commensurate with the risk and potential impact of a radiological release
   h. Simplification of training, exercise, and drill requirements.

NRC documentation of its responses to the above objectives and corresponding revisions to this paper will provide an agreed basis for related issues to be properly addressed in the NGNP Project license application.

5. REFERENCES

ACRS, 2004, "Options and Recommendations for Policy Issues Related to Licensing Non-Light Water Reactor Designs." April 22, 2004.

ACRS, 2006, "Proposed Revision to Standard Review Plan Section 13.3, "Emergency Planning." December 15, 2006.

ACRS, 2007, "Technology-Neutral Framework for Future Plant Licensing." April 20, 2007.

ACRS, 2008, "Historical Perspectives and Insights on Reactor Consequence Analyses." November 2008.

DHS, 2008, National Response Framework, U.S. Department of Homeland Security. January 2008.

DiNunno, J. J. et al., 1962, "Calculation of Distance Factors for Power and Test Reactor Sites," Technical Information Document (TID-14844), U.S. Atomic Energy Commission. March 1962.

DOE/NRC, 2008, "Next Generation Nuclear Plant Licensing Strategy – A Report to Congress," Joint Report of the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission. August 2008.

EPA, 1980, "Manual of Protective Actions for Nuclear Incidents," EPA-520/1-75-001-A, U.S. Environmental Protection Agency. January 1980.

EPA, 1988, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, Federal Guidance Report No. 11" EPA-520/1-88-020. September 1988.

EPA, 1992, "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents," EPA 400-R-92-001, U.S. Environmental Protection Agency. May 1992.

EPA, 1993, "External Exposure to Radionuclides in Air, Water, and Soil, Federal Guidance Report No. 12," EPA 402-R-93-081. September 1993.

EPA, 2010, "Protective Action Guides - Radiation Protection - US EPA." US Environmental Protection Agency, Website. 11 June 2010. <http://www.epa.gov/rpdweb00/rert/pags.html#status>.

FEMA, 2009, "Developing and Maintaining State, Territorial, Tribal, and Local Government Emergency Plans," Comprehensive Preparedness Guide 101, Federal Emergency Management Agency. March 2009.

INL, 2009, "Next Generation Nuclear Plant Defense in Depth Approach," INL/EXT-09-17319, Idaho National Laboratory. December 2009.

INL, 2010, "Mechanistic Source Term White Paper," INL/EXT-10-17997, (ML102040260) Idaho National Laboratory. July 2010.

INL, 2010a, "NGNP Fuel Qualification White Paper," INL/EXT-10-17686, (ML102040261) Idaho National Laboratory. July 2010.

INL, 2010b, "Licensing Basis Event Selection White Paper," INL/EXT-10-19521, Idaho National Laboratory. September 2010.

Leaver, D., 2007, "Risk-Informed Evaluation of Protective Action Strategies for Nuclear Plant Off-Site Emergency Planning," Polestar Applied Technology, Inc., EPRI, NEI. September 2007.

NRC, 1978, NUREG-0396, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants," U. S. Nuclear Regulatory Commission. December 1978.

NRC, 1978a, Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)," Revision 3, U.S. Nuclear Regulatory Commission. November 1978.

NRC, 1980, NUREG-0654/FEMA-REP-1, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," Revision 1, U.S. Nuclear Regulatory Commission. November 1980.

NRC, 1989, NUREG-1338, "Draft Preapplication Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor," U.S. Nuclear Regulatory Commission. February 1989.

NRC, 1990, SECY 90-0341, "Staff Study on Source Term Update and Decoupling Siting from Design," U.S. Nuclear Regulatory Commission. October 4, 1990.

NRC, 1994, NUREG-1368, "Preapplication Safety Evaluation Report for the Power Reactor Innovative Small Module (PRISM) Liquid-Metal Reactor," U.S. Nuclear Regulatory Commission. February 1994.

NRC, 1995, NUREG-1338, "Draft Preapplication Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor," U.S. Nuclear Regulatory Commission. December 1995.

NRC, 1997, SECY 97-0020, "Results of Evaluation of Emergency Planning for Evolutionary and Advanced Reactors," U.S. Nuclear Regulatory Commission. January 27, 1997.

NRC, 1998, Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations," Revision 2, U.S. Nuclear Regulatory Commission. April 1998.

NRC, 2000, NUREG-1614, "Strategic Plan," Volume 2, Part 2, U.S. Nuclear Regulatory Commission. February 2000.

NRC, 2000a, Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," U.S. Nuclear Regulatory Commission. July 2000.

NRC, 2002, SECY 02-0139, "Plan for Resolving Policy Issues Related to Licensing Non-Light Water Reactor Designs," U.S. Nuclear Regulatory Commission. July 22, 2002.

NRC, 2003, SECY 03-0047, "Policy Issues Related to Licensing Non-Light-Water Reactor Designs," U.S. Nuclear Regulatory Commission. March 23, 2003.

NRC, 2003a, SECY 03-0059, "NRC's Advanced Reactor Research Program," U.S. Nuclear Regulatory Commission. April 18, 2003.

NRC, 2004, NUREG-1614, "Strategic Plan," Volume 3, U.S. Nuclear Regulatory Commission. August 2004.

NRC, 2004a, Regulatory Guide 1.101, "Emergency Planning and Preparedness for Nuclear Power Reactors," U.S. Nuclear Regulatory Commission. June 2004.

NRC, 2005, 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," U.S. Nuclear Regulatory Commission. January 7, 2005.

NRC, 2007, NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Chapter 13.3, Rev. 3, U.S. Nuclear Regulatory Commission. March 2007.

NRC, 2007a, NUREG-1860, "Feasibility Study for a Risk-Informed and Performance-Based Regulatory Structure for Future Plant Licensing, Volumes 1 and 2," U.S. Nuclear Regulatory Commission. December 2007.

NRC, 2007b, Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," U.S. Nuclear Regulatory Commission. June 2007.

NRC, 2008, NUREG-1614, "Strategic Plan," Volume 4, U.S. Nuclear Regulatory Commission. January 2008.

NRC, 2009, SECY 09-0056, "Staff Approach Regarding a Risk-Informed and Performance-Based Revision to Part 50 of Title 10 of the Code of Federal Regulations and Developing a Policy Statement on Defense-in-Depth for Future Reactors," U.S. Nuclear Regulatory Commission. April 7, 2009.

NRC, 2009a, SECY 09-0007, "Proposed Rule Related to Enhancements to Emergency Preparedness Regulations (10 CFR Part 50) (RIN 3150-AI10)," U.S. Nuclear Regulatory Commission. January 2009.

NRC, 2010, NUREG-1635, "Review and Evaluation of the Nuclear Regulatory Commission Safety Research Program: A Report to the U.S. Nuclear Regulatory Commission," Volume 9, U.S. Nuclear Regulatory Commission. March 2010.

NRC, 2010a, SECY 10-0034, "Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs," U.S. Nuclear Regulatory Commission. March 28, 2010.

Philadelphia Electric Company, 1964, Peach Bottom Atomic Power Station, Final Hazards Summary Report, NP-9115, Philadelphia Electric Company. March 1964.

Public Service Company of Colorado, 1991, "Fort St. Vrain Unit No. 1 Updated Final Safety Analysis Report," Rev. 9, U.S. Nuclear Regulatory Commission Docket No. 50-267. July 1991.

Ross, S.B., Rishel, J.P., Lowry, P.P., 2010, Pacific Northwest National Laboratory, "Engineering Evaluation of χ/Q Values Consistent with Regulatory Guide 1.145," PNNL-19217. February, 2010.

Appendix A

Assessment of Interfaces with, and Requirements of, Coordinating Agencies (e.g., within the National Response Framework)

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Assessment of Interfaces with, and Requirements of, Coordinating Agencies (e.g., within the National Response Framework)

Emergency plans must be coordinated among all levels of government to ensure an effective response. The goal is to ensure the effectiveness of combined Federal and State, Territorial, Tribal, and local operations through integration and synchronization. To help accomplish this, Federal Emergency Management Agency (FEMA) Comprehensive Preparedness Guide (CPG) 101, Developing and Maintaining State, Territorial, Tribal, and Local Government Emergency Plans (CPG-101) (FEMA 2009) integrates emergency management concepts discussed in the National Response Framework (NRF; DHS 2008). The NRF is a guide to how the nation conducts all-hazards response. Together, CPG-101 and the NRF are part of a larger federal disaster planning effort. CPG-101 provides emergency managers and other emergency services personnel with recommendations on how to address the entire planning process. It also encourages emergency managers to follow a process that addresses all of the hazards that threaten their jurisdiction through a suite of plans connected to a single, integrated emergency operations plan (EOP).

FEMA CPG 101 provides general guidelines on developing EOPs. It promotes a common understanding of the fundamentals of emergency planning and decision making to help emergency planners examine a hazard and produce integrated, coordinated, and synchronized emergency plans. Because the effects of an emergency are not necessarily dependent on the cause of the emergency, emergency planners can address common operational functions in a basic emergency plan instead of having unique plans for every type of hazard or threat.

For example, floods, wildfires, hazardous materials releases, and radiological emergencies can all lead a jurisdiction to issue an evacuation order. Even though the characteristics (e.g., speed of onset, size of the affected area) of a particular hazard are different, the general tasks for conducting an evacuation are the same. While differences in the speed of onset may affect when an order to evacuate is given, the process of determining the need for evacuation and issuing the order does not change. All-hazards and all-threats planning ensures that, when addressing emergency functions, planners identify common tasks and who is responsible for accomplishing those tasks. Emergency plans developed for the HTGR should take advantage of existing state and local emergency plans.

State and local emergency plans developed using FEMA's CPG 101, as a guide, may utilize the same emergency support function (ESF) plan structure used in the NRF. Likewise, the Federal Government and many state governments organize much of their resources and capabilities, as well as those of certain private-sector and nongovernmental organizations, under the 15 ESFs outlined in the NRF. The ESF structure organizes resources by category, kind, size, capacity, skill, and other characteristics. This organization makes resource management more efficient and ensures that similar resources from different agencies are organized according to standard principles. ESF coordinators and primary agencies are identified on the basis of authorities and resources. Support agencies are assigned based on the availability of resources in a given functional area.

The 16 planning standards and associated evaluation criteria presented in NUREG-0654 can be integrated into state and local EOPs based on the NRF. The following two tables help illustrate this integration. Table A-1 provides a generic description of the role of each ESF during an emergency. Table A-2 demonstrates how these ESFs can be directly related to the 16 planning standards and

associated evaluation criteria that are included in corresponding planning information in a typical state or local all-hazards EOP utilizing the NRF.

Table A-1. Description of ESFs used in the National Response Framework.

ESF	Description
#1 – Transportation	Provides coordination of ground transportation assistance and designation/maintenance of traffic routes that may be required following a significant natural disaster or technological event. Addresses support to implement protective action strategies of evacuation and shelter in-place. Identifies and meets the transportation needs of victims and emergency service responders during a major emergency or disaster.
#2 – Communications	Outlines the emergency communications systems and capability of emergency services agencies; describes methods of communicating with higher authority and neighboring jurisdictions, and the public; and describes system components and task assignments to assure effective communications during emergencies Provides for a notification system capable of disseminating adequate and timely alerts to the public and government officials in the event of an impending disaster situation.
#3 – Public Works and Engineering	Provides guidance for the provision of emergency technical advice, evaluations, and engineering services to assure the safety of emergency responders and the public and to continue or restore critical public works. This may include construction management and inspections, emergency contracting, emergency repairs of wastewater and solid waste facilities. Facilitates and coordinates the management (removal, collection, and disposal) of debris following a disaster in order to mitigate against any potential threat to the lives, health, safety, and welfare of the impacted citizens, expedites recovery efforts in the impacted area, and addresses any threat of significant damage to improved public property.
#4 – Firefighting	Coordinates fire and rescue activities to ensure the safety of life and property during emergency situations.
#5 – Emergency Management	Provides a guideline for the collection, processing, and dissemination of information about a potential or actual disaster or emergency to facilitate effective and efficient response.
#6 – Mass Care, Emergency Assistance, Housing, and Human Services	Coordinates activities involved with the emergency provision of temporary shelters, emergency mass feeding, bulk distribution of coordinated relief supplies for victims of disaster, and disaster welfare information.
#7 – Logistics Management and Resource Support	Provides logistical and resource support to agencies involved in emergency response and recovery efforts. This includes emergency relief supplies, office space, office equipment, office supplies, telecommunications, contracting services, transportation services (in coordination with ESF #1), and personnel required for immediate response activities.
#8 – Public Health and Medical Services	Outlines a system to ensure the provision of health and medical resources and emergency medical services required to support the emergency needs resulting from a major emergency or disaster.

Table A-1. (continued).

ESF	Description
#9 – Search and Rescue	Provides information and procedures to help facilitate search and rescue including life-saving assistance.
#10 – Oil and Hazardous Materials Response	Provides guidance for operations in response to emergencies resulting from the manufacture, use, storage, and transfer of hazardous materials; describes the specific roles and responsibilities of first responders utilizing a standardized Incident Command System; and coordinates the emergency response capabilities of local, state, and federal agencies, adjacent jurisdictions, private industry, and volunteers
#11 – Agriculture and Natural Resources	Identifies food and water needs in the aftermath of a disaster or emergency, obtains resources needed to meet these needs, and transports such resources to the disaster area. Provides animal and plant disease/pest response. Provides guidance for the protection and restoration of natural and cultural resources and historic properties. Provides guidance on establishing a method of veterinary medicine and animal care resources in emergency preparedness, response, recovery, and mitigation management.
#12 – Energy	Coordinates providing emergency power and fuel to support immediate response operations and providing power and fuel to stabilize the community.
#13 – Public Safety and Security	Establishes a mechanism that efficiently provides and disseminates information to the general public in the event of a disaster.
#14 – Long-Term Community Recovery	Provides a framework for recovery from the long-term consequences of an emergency. This support includes stabilization of regional and local economies, using available programs and resources of State and Federal departments and agencies to aid community recovery, especially long-term recovery, and reducing or eliminating risk from future incidents, where feasible.
#15 – External Affairs	Establishes a mechanism that efficiently provides and disseminates information to the general public in the event of a disaster.

Table A-2. Comparison of 10 CFR 50.47 Planning Standards with the ESFs used in the National Response Framework.

NUREG-0654 Planning Standard	All-Hazards Plan Reference
A. Assignment of Responsibility (Organizational Control) Primary responsibilities for emergency response by the nuclear facility licensee, and by State and local organizations within the Emergency Planning Zones have been assigned, the emergency responsibilities of the various supporting organizations have been specifically established, and each principal response organization has staff to respond and to augment its initial response on a continuous basis.	Basic Plan ESF #10 – Oil and Hazardous Materials Response
B. Onsite Emergency Organization On-shift facility licensee responsibilities for emergency response are unambiguously defined, adequate staffing to provide initial facility accident response in key functional areas is maintained at all times, timely augmentation of response capabilities is available, and the interfaces among various onsite response activities and offsite support and response activities are specified.	Not applicable to offsite emergency planning. Applicable only to onsite emergency plans
C. Emergency Response Support and Resources Arrangements for requesting and effectively using assistance resources have been made, arrangements to accommodate State and local staff at the licensee's near-site Emergency Operations Facility have been made, and other organizations capable of augmenting the planned response have been identified.	Basic Plan ESF #7 – Logistics Management and Resource Support
D. Emergency Classification System A standard emergency classification and action level scheme, the bases of which include facility system and effluent parameters, is in use by the nuclear facility licensee, and State and local response plans call for reliance on information provided by facility licensees for determinations of minimum initial offsite response measures.	Basic Plan ESF #5 – Emergency Management
E. Notification Methods and Procedures Procedures have been established for notification, by the licensee of State and local response organizations and for notification of emergency personnel by all response organizations; the content of initial and follow-up messages to response organizations and the public has been established; and means to provide early notification and clear instruction to the populace within the plume exposure pathway Emergency Planning Zone have been established.	ESF #2 – Communications ESF #5 – Emergency Management ESF #13 – Public Safety and Security ESF #15 – External Affairs

Table A-2. (continued).

NUREG-0654 Planning Standard	All-Hazards Plan Reference
F. Emergency Communications Provisions exist for prompt communications among principal response organizations to emergency personnel and to the public.	ESF #2 – Communications ESF #5 – Emergency Management ESF #13 – Public Safety and Security ESF #15 – External Affairs
G. Public Education and Information Information is made available to the public on a periodic basis on how they will be notified and what their initial actions should be in an emergency (e.g., listening to a local broadcast station and remaining indoors), the principal points of contact with the news media for dissemination of information during an emergency (including the physical location or locations) are established in advance, and procedures for coordinated dissemination of information to the public are established.	ESF #2 – Communications ESF #5 – Emergency Management ESF #13 – Public Safety and Security ESF #15 – External Affairs
H. Emergency Facility and Equipment Adequate emergency facilities and equipment to support the emergency response are provided and maintained.	ESF #3 – Public Works and Engineering ESF #7 – Logistics Management and Resource Support
I. Accident Assessment Adequate methods, systems, and equipment for assessing and monitoring actual or potential offsite consequences of a radiological emergency condition are in use.	ESF #3 – Public Works and Engineering ESF #7 – Logistics Management and Resource Support
J. Protective Response A range of protective actions have been developed for the plume exposure pathway EPZ for emergency workers and the public. Guidelines for the choice of protective actions during an emergency, consistent with Federal guidance, are developed and in place, and protective actions for the ingestion exposure pathway EPZ appropriate to the locale have been developed.	ESF #5 – Emergency Management ESF #11 – Agriculture and Natural Resources
K. Radiological Exposure Control 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.	ESF #4 – Firefighting ESF #6 – Mass Care, Emergency Assistance, Housing, and Human Services ESF #8 – Public Health and Medical Services ESF #13 – Public Safety and Security
L. Medical and Public Health Support Arrangements are made for medical services for contaminated injured individuals.	ESF #1 – Transportation ESF #8 – Public Health and Medical Services ESF #13 – Public Safety and Security
M. Recovery and Reentry Planning and Post-accident Operations General plans for recovery and reentry are developed.	ESF #14 – Long-Term Community Recovery

Table A-2. (continued).

NUREG-0654 Planning Standard	All-Hazards Plan Reference
N. Exercises and Drills Periodic exercises are (will be) conducted to evaluate major portions of emergency response capabilities, periodic drills are (will be) conducted to develop and maintain key skills, and deficiencies identified as a result of exercises or drills are (will be) corrected.	Basic Plan
O. Radiological Emergency Response Training Radiological emergency response training is provided to those who may be called on to assist in an emergency.	Basic Plan
P. Responsibility for the Planning Effort: Development, Periodic Review, and Distribution of Emergency Plans Responsibilities for plan development and review and for distribution of emergency plans are established, and planners are properly trained.	Basic Plan

The NRF also contains incident annexes that address unique aspects of response to several broad incident categories, including a nuclear/radiological incident. The incident annexes describe the concept of operations to address specific contingency or hazard situations or an element of an incident requiring specialized application of the NRF. The overarching nature of functions described in these annexes frequently involves either support to or cooperation of all federal departments and agencies involved in incident management efforts to ensure seamless integration of and transitions between preparedness, prevention, response, recovery, and mitigation activities.

The Nuclear/Radiological Incident Annex (NRIA) to the NRF describes the policies, situations, concepts of operations, and responsibilities of the federal departments and agencies governing the immediate response and short-term recovery activities for incidents involving release of radioactive materials to address the consequences of the event. According to the NRIA to the NRF, the following concept of operations is applicable to:

> *The owner/operator of a nuclear/radiological facility or materials (e.g., DOE, DOD, or NRC licensee) primarily is responsible for mitigating the consequences of an incident; providing notification and appropriate protective action recommendations to State, local, and/or tribal government officials; and minimizing the radiological hazard to the public. For incidents involving fixed facilities, the owner/operator has primary responsibility for actions within the facility boundary and may also have responsibilities for response and recovery activities outside the facility boundary under applicable legal obligations (e.g., contractual; licensee; CERCLA). For areas surrounding a nuclear/radiological incident location, State, tribal, and local governments have primary responsibility for protecting life, property, and the environment. This does not, however, relieve nuclear/radiological facility or material owners/operators from applicable legal obligations.*
>
> *State, tribal, and local governments and owners/operators of nuclear/radiological facilities or activities should request assistance through established regulatory communication and response protocols. However, they may request assistance directly from DHS, other Federal agencies, and/or State*

governments with which they have preexisting arrangements or relationships, providing that the agency with regulatory authority is also notified.

The initial response is typically handled at the local level. Local responders are responsible for implementing an Incident Command System (ICS) to manage the incident response. Federal agencies will integrate into the Incident Command (IC) in support of the local jurisdictions.

With respect to notification, the NRIA to the NRF states:

The owner/operator of a nuclear/radiological facility or owner/transporter of nuclear/radiological material is generally the first to become aware of an incident and notifies State, tribal, and local authorities and the coordinating agency.

Federal, State, tribal, and local governments that become aware of a radiological incident should notify the coordinating agency and the DHS National Operations Center (NOC) and comply with other appropriate statutory requirements for notification. For example, releases of reportable quantities of any listed hazardous materials as described within 40 CFR Part 302 must be reported to the National Response Center. Further, State, tribal, and local law enforcement agencies should continue to contact the local FBI/Joint Terrorism Task Force regarding ongoing terrorist activities, events, instances, or investigations. The coordinating agency provides notification of a radiological incident to the NOC and other Federal agencies, as appropriate. If a State requests radiological assistance directly from a Federal agency for a nuclear/radiological incident that falls under the jurisdiction of another coordinating agency, that Federal agency shall notify the coordinating agency of the request.

With respect to activation, the NRIA to the NRF states:

Once notified, the coordinating agency initiates response in accordance with its authorities. DHS reviews the situation and determines whether to assume Federal leadership for the overall response in accordance with the NRF.

Coordinating agencies and cooperating agencies provide representatives to the NRF elements (e.g., JFO, NOC, etc.) when appropriate. For Stafford Act incidents, DHS/FEMA may issue mission assignments to Federal agencies to support such activities.

If DHS does not assume Federal leadership for the response, a coordinating agency may request that DHS activate NRF elements to support the response. The coordinating agency may request assistance from other Federal agencies.

The coordinating agency also will be represented in appropriate positions within the Command Staff in the IC/UC structure (as defined by NIMS), and coordinates Federal radiological response activities at appropriate field facilities. 6 Coordinating agencies and cooperating agencies provide personnel to other sections of the IC/UC as needed.

For any nuclear/radiological incident, the coordinating and cooperating agencies may establish a field facility; assist State, tribal, and local response organizations; monitor and support owner/operator activities (when there is an owner or operator); provide technical support to the owner/operator, if

requested; and serve as a Federal source of information about incident conditions.

The NRIA to the NRF is applicable whenever a federal response is undertaken unilaterally pursuant to federal authorities, or when an incident exceeds or is anticipated to exceed state, tribal, or local resources. The federal government's response structures are scalable and flexible and are adaptable specifically to the nature and scope of a given event (DHS 2008). Based on the unique characteristics of the HTGR, a federal response beyond notification of the appropriate coordinating agency in accordance with the NRF is not anticipated.

In addition to the NRIA, state and local EOPs developed using FEMA's CPG 101 ESF plan structure include, as attachments, separate support or incident annexes. These annexes describe in detail the information outlined in the EOP basic plan and describe the framework through which a jurisdiction's departments and agencies, the private sector, not-for-profit and voluntary organizations, and other nongovernmental organizations coordinate and execute the common emergency management strategies. The actions described in the support annexes apply to nearly every type of emergency.

The incident annexes describe the policies, situation, concept of operations, and responsibilities for particular hazards or incident types (i.e., biological, catastrophic, cyber, food and agriculture, nuclear/radiological, oil and hazardous materials, terrorism, and other hazards as required). Each incident annex typically has the following four sections: (1) The policy section identifies the authorities unique to the incident type, the special actions or declarations that may result, and any special policies that may apply; (2) The situation section describes the incident or hazard characteristics and the planning assumptions and outlines the management approach for those instances when key assumptions do not hold (e.g., how authorities will operate if they lose communication with senior decision makers); (3) The Concept of Operations describes the flow of the emergency management strategy for the specific incident, hazard, or threat addressed in the annex and identifies special coordination structures, specialized response teams or unique resources needed, and other special considerations unique to the type of incident or hazard; and (4) Each incident annex identifies the coordinating and cooperating agencies involved in an incident-, hazard-, or threat-specific response.

In addition, the incident annexes identify strategies for detecting, assessing, and controlling the hazard; warning and protecting the public; and returning the area to a state of normalcy and identifying potential state and federal resources that may be needed should the hazard exceed the local capabilities.

Any offsite emergency plans developed for the HTGR would likely be developed as a NRIA in the offsite emergency plans if one does not already exist for another radiological hazard.