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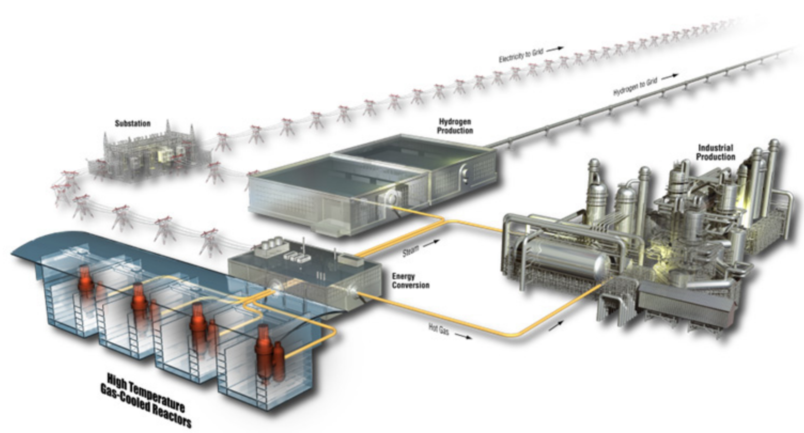
Revision 1

NRC Licensing Status Summary Report for NGNP

November 2014



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November 2014

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EXECUTIVE SUMMARY

In 2005, the U.S. Department of Energy (DOE) established the Next Generation Nuclear Plant (NGNP) Project at the Idaho National Laboratory (INL). This action supported near-term commercial deployment of a high temperature, gas-cooled reactor (HTGR) technology demonstration plant.

NGNP undertook a variety of studies and actions related to HTGR technology research and development, the conceptual plant design, systems engineering, and development of a regulatory framework supportive of commercial HTGR deployment. Framework activities were closely coordinated with Nuclear Regulatory Commission (NRC) staff and focused on adapting existing nuclear power plant regulatory requirements to the needs of NGNP licensing. The approach for this licensing structure was jointly formulated by DOE and NRC and communicated to Congress in 2008.

This report summarizes major activities, regulatory framework developments, and the status of NGNP prelicensing efforts as of August 2014.

NGNP systematically examined HTGR licensing precedents and NRC regulations as they relate to the NGNP safety case and associated plant design goals. The scope and results of this examination were coordinated with and reviewed by NRC staff. In 2009, NGNP used this information to develop a strategic implementation plan for establishing the regulatory basis necessary to complete and submit a HTGR license application to NRC. The plan focused on key elements of plant safety design and licensing and included:

- Developing the basis for establishing a mechanistic radiological source term (based primarily on particle fuel design and available qualification testing results)
- Preventing/mitigating the release of the radiological source terms to the environment, including methods for the structured and comprehensive identification of licensing basis event sequences, along with establishing multiple radionuclide release barriers
- Developing an updated emergency planning structure that considers collocated industry energy end-users to assure protection of public health and safety in the unlikely event of a radiological release.

The design and licensing strategy of NGNP centered on radionuclide retention capabilities of the tristructural isotropic (i.e., TRISO) particle fuel. It also relied less on other barriers for limiting offsite releases of radionuclides. This strategy—along with related HTGR design goals—aligns with NRC's Advanced Reactor Policy Statement regarding pursuit of less complex reactor designs with longer response time constants, passive reactor shutdown and passive heat removal with limited reliance on operator actions, minimization of severe accident potential, and providing multiple barriers to potential radionuclide releases.

A key NGNP methodology in addressing this strategy was to document proposed approaches in a series of complementary prelicensing "white papers". Each white paper included a specific set of outcome objectives that support NGNP licensing and was developed with inputs from DOE and the NGNP Licensing Working Group. The NGNP Licensing Working Group included representatives from three domestic HTGR design firms, an owner-operator organization, and staff from NGNP Regulatory Affairs. White papers were submitted to NRC staff for formal review and feedback. The review and feedback process included extensive public meeting interactions, conference calls, and written correspondence focused on requests for additional information.

In early 2012, NGNP's DOE/INL team and NRC staff jointly identified and agreed to focus near-term discussions on four key licensing framework topics. These four topics were areas of significant and longstanding regulatory uncertainty for the entire HTGR industry. The four key topical areas targeted for joint examination were:

- HTGR containment functional performance
- Licensing basis event selection
- Source terms
- Emergency planning.

Ensuing interactions resulted in NRC staff drafting initial regulatory positions on the four framework topics and submitted them to the NRC's Advisory Committee on Reactor Safeguards (ACRS) for review in early 2013. Staff findings were then updated and again released in July 2014. Major items addressed in that NRC staff position report included:

- The INL Advanced Gas Reactor (AGR) Fuel Program was determined to be reasonably complete within a context of pre-prototype fuel testing. Early fuel test results showed promise in demonstrating much of the desired retention capabilities of the TRISO particle fuel. Additional information from special tests in the first operating HTGR unit will most likely be necessary to confirm that the coated particle fuel developed for NGNP retains fission products as predicted.
- General agreement was expressed with the proposed NGNP performance standard concerning HTGR functional containment. The functional containment approach limits radionuclide releases to the environment by emphasizing retention of radionuclides at their source in the fuel rather than allowing significant fuel particle failures and relying upon other external barriers to assure compliance with identified top level regulatory dose acceptance criteria.
- The licensing basis event identification and categorization process proposed by NGNP included a frequency versus consequence approach for evaluating postulated event sequences against top-level regulatory criteria (primarily offsite dose). Initially, based on public meeting discussions and a draft feedback summary written by NRC staff, this approach appeared to be generally reasonable. However, some members of the staff believed that a supplement was probably necessary to DOE/INL's proposed set of design basis accidents (DBAs). This supplement entailed additional deterministically postulated accidents. NGNP personnel felt that adding events from outside the proposed event selection process created significant uncertainty for the industry. The concept of a supplement was also subject to challenge by ACRS recommendations. This issue (and other related topics) was not addressed in the July 2014 NRC staff position report. The omission on this topic, as well as the overall licensing basis event identification and categorization process in general, was attributed to staff concerns that issuing feedback on the topic now might be inconsistent with ongoing NRC efforts related to post-Fukushima Near Term Task Force (NTTF) Recommendation 1 and subsequent development of a risk management regulatory framework.
- The proposed mechanistic methodology for defining and evaluating source terms was reasonable to NRC staff.
- The staff was receptive to future emergency planning proposals for a probabilistic risk assessment (PRA) informed approach in sizing the emergency planning zone. Proposals might include use of accident dose assessments when determining an appropriate emergency planning zone size (see NRC's SECY 11-0152, which contains a partial response to NGNP white paper proposals). However, clarification beyond SECY 11-0152 was not provided due to the need for Commission action on related policy issues. Further staff evaluation of the NGNP emergency planning approach was curtailed pending availability of more site and plant design information.

NRC staff findings published thus far on the proposed NGNP approaches are not legally binding because, as the staff clearly pointed out during their interactions, the regulatory evaluations are not part of a formal license application. Similarly, certain key issues will require Commission policy determinations before they can proceed. Despite this, staff indicated general agreement with the systematic approaches proposed by NGNP and understood them to provide a reasonably sound basis for developing a license application. However, significant licensing issues remain to be addressed by license applicants through direct NRC staff interaction.

NGNP Regulatory Affairs undertook additional activities to support NGNP deployment. These efforts included:

- Developing and delivering a comprehensive HTGR technology training course to a large number of NRC staff
- Performing two site hazard assessments to better inform subsequent NGNP design/licensing strategies and identify/address likely site hazards and constraints when siting modular HTGRs in a collocated industrial setting
- Performing a detailed regulatory gap analysis that examined over 2,500 individual regulatory requirements and implementing pieces of guidance for NGNP applicability
- Developing key portions of an HTGR-compatible Combined License Application Format and Content Guide structured similar to NRC's current light water reactor guidance (RG 1.206).

Unresolved Commission policy issues remain the key source of regulatory uncertainty for modular HTGRs. Therefore, industry stakeholders and future license applicants should continue to engage the NRC and encourage that the NGNP approaches already found reasonable by the staff be forwarded to the Commission to initiate associated policy actions. Additional work related to licensing event selection, source terms, the emergency planning zone size, and functional containment performance should resume early in the license application development process.

CONTENTS

FIGURES

TABLE

ACRONYMS

ACRS	Advisory Committee on Reactor Safeguards
ADAMS	agency wide documents access and management system
AE	anticipated events
AGR	advanced gas reactor
ANS	American Nuclear Society
AOO	anticipated operational occurrence
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATR	Advanced Test Reactor
ART	Advanced Reactor Technologies
BDBE	beyond design basis event
BPV	boiler pressure vessel
CDF	core damage frequency
CFR	code of federal regulations
COLA	combined license application
DBA	design basis accidents
DBE	design basis event
DC	design certification
DDN	data design needs
DID	defense-in-depth
DOE	Department of Energy
DOE-NE	Department of Energy, Office of Nuclear Energy
DSRP	design-specific review plan
EAB	exclusion area boundary
EP	emergency planning
EPA	Environmental Protection Agency
EPAct	Energy Policy Act of 2005
EPZ	emergency planning zone
ESBWR	economic simplified boiling-water reactor
F-C	frequency-consequence
FSAR	final safety analysis report
FY	fiscal year
GDC	general design criteria

HTGR	high temperature gas-cooled reactor
IHX	intermediate heat exchanger
INL	Idaho National Laboratory
JCNRM	Joint Committee on Nuclear Risk Management
LBE	licensing basis events
LERF	large early release frequency
LWG	Licensing Working Group
LWR	light water reactor
MHTGR	Modular High-Temperature Gas-Cooled Reactor
MOU	memorandum of understanding
NEAC	Nuclear Energy Advisory Committee
NEI	Nuclear Energy Institute
NGNP	Next Generation Nuclear Plant
NRC	Nuclear Regulatory Commission
NSRST	non-safety related with special treatment
NTTF	Near Term Task Force
OL	operating license
PAG	protective action guides
PBMR	pebble-bed modular reactor
PDC	principal design criteria
PPE	plant parameter envelop
PRA	probabilistic risk assessment
PSAR	preliminary safety analysis report
QA	Quality Assurance
QAPD	quality assurance program description
QHO	quantitative health objectives
R&D	research and development
RAI	request for additional information
RG	regulatory guide
RGA	regulatory gap analysis
RIPB	risk informed performance based
RIS	regulatory issues summary
RMRF	Risk Management Regulatory Framework
RPV	reactor pressure vessel
SAFDL	specified acceptable fuel design limit

SARRDL	specified acceptable core radionuclide release limit
SMR	small modular reactor
SRM	staff requirements memorandum
SRP	standard review plan
SSC	structures, systems, and components
TDO	Technology Development Office
TEDE	total effective dose equivalent
TLRC	top-level regulatory criteria
TRISO	tristructural isotropic
VHTR	very high temperature reactor

NRC Licensing Status Summary Report for NGNP

1. OVERVIEW

1.1 Purpose

The U.S. Department of Energy (DOE) initiated the Next Generation Nuclear Plant (NGNP) at Idaho National Laboratory (INL) pursuant to provisions of the Energy Policy Act (EPAct) of 2005.[1] NGNP was established to advance research and development (R&D) in support of the DOE Generation IV Nuclear Energy Systems Initiative. NGNP supports commercializing modular high temperature, gas-cooled reactor (HTGR) technology. The modular HTGR uses helium to remove heat from a graphite-moderated reactor core and can operate at temperatures much higher than conventional light water reactors (LWR).

The U.S. Nuclear Regulatory Commission (NRC) will license NGNP for construction and operation. However, because the domestic commercial reactor fleet currently employs LWR technology, not all elements of existing nuclear reactor regulation (and related guidance for regulatory implementation) apply to HTGR technology. Certain policies and requirements, established primarily with consideration of LWR licensing need, must be adapted or in some limited cases, newly created to address fundamental differences in HTGR design elements and safety approaches. Using NGNP as a venue for cooperative effort between DOE and NRC, a strategy was established and implemented for licensing HTGR technology in the United States.

This report provides a synopsis of the NGNP initiative with respect to developing an HTGR-compatible domestic licensing framework. The report: (1) describes NGNP's licensing framework development activities and status through August 2014, and (2) provides observations and recommendations concerning key licensing activities that remain for future applicants.

1.2 Background

The U.S. nuclear energy industry has relied upon LWR technology for generating large amounts of base-load electricity. However, LWR technology is limited to a process steam temperature of approximately 300°C. HTGR technology can provide steam (for electricity and process heating) and high temperature heat approaching 925°C for industrial processes. A modular HTGR unit can reliably supply high temperature process heat for 60-years or more and offers a viable alternative to many industrial applications currently relying on carbon-based fuels. Multiple HTGR heat applications can exist at the same facility and includes systems for co-generation of steam and electricity, high temperature heat for petrochemical and refining plants, hydrocarbon recovery in oil sand formations, and the production of hydrogen gas. Innovative applications of HTGR technology can significantly reduce the use of premium fossil fuels and reduce commensurate release of greenhouse gases while maintaining public safety.

Recognizing the broad national and international strategic interest served by nuclear power, DOE initiated the Generation IV Nuclear Systems program (Gen IV) in fiscal year (FY) 2002. The mission of the Gen IV addresses critical unanswered questions about advanced nuclear reactor technologies through R&D. This R&D helps establish viability of next generation nuclear energy systems and provides results useful in extending the operating life of all classes of reactors. The modular HTGR is one of the Gen IV advanced nuclear technologies.

The EPAct 2005 (Public Law 109-58), Title VI, Subtitle C, directed DOE to establish a project known as the NGNP. Accordingly, NGNP included R&D, design, licensing, and construction activities for the technology conducted in two phases. These phases would lead to the operation of an NRC-licensed prototype Gen IV reactor and associated energy delivery system.

Phase 1 addresses selecting and validating appropriate support technologies, carrying out enabling research, development, and demonstration activities, determining whether it is appropriate to combine electricity generation and hydrogen production in a single prototype nuclear reactor plant, and carrying out the initial design of a prototype reactor and plant. This includes developing design methods and safety analytical methods and studies.

Phase 2 develops a final design for the prototype nuclear reactor and plant through a competitive process. It also includes applying to NRC for a license to construct and operate the prototype nuclear reactor. It addresses construction/startup operations for the prototype nuclear reactor and its associated hydrogen or electricity production facilities.

Both phases include R&D and licensing activities. Once built, the prototype reactor would then produce hydrogen and/or electricity and demonstrate other uses for the high temperature process heat generated by the reactor. The prototype reactor design would be generic enough that replicate plants can be sited at other locations within the U.S.

In August 2008, the DOE "NGNP Licensing Strategy Report to Congress,"[2] outlined a recommended licensing strategy for satisfying the EPAct of 2005. As further discussed in Section 3.1 of this status report, the Licensing Strategy was jointly developed by NRC and DOE and provided a high-level plan concerning R&D, licensing, construction, and deployment of HTGR technology. This plan would to be completed by adapting existing LWR regulations to NGNP.

Another DOE "Report to Congress"[3] was completed in 2010. This document updated the NGNP Combined License Application (COLA) submittal schedule originally contained in the August 2008 Report. Letters sent to select members of Congress (dated October 17, 2011)[4] advised that the public-private partnership formed under NGNP will be responsible to provide COLA-related schedule and milestone updates.

Given fiscal constraints imposed by the U.S. Government during FY2011 and beyond, competing priorities within DOE, projected costs associated with initial plant deployment, and delays in reaching a NGNP cost-sharing agreement with private industry, DOE chose not to proceed with Phase 2 NGNP design activities at that time. The October 17, 2011, letters to Congress stated that NGNP would continue at a reduced activity level with emphasis on continuing essential high temperature reactor R&D, conducting interactions with NRC staff on developing an HTGR-compatible licensing framework, and establishing the public-private partnership. Continuation of these activities would enable NGNP Phase 2 activities to proceed later.

This report discusses the licensing framework development activities, progress, and status of prelicensing activities produced from NGNP Phase 1 work.

2. PROJECT ORGANIZATION AND INTERFACE

2.1 Department of Energy

The U.S. DOE Office of Nuclear Energy (DOE-NE) is tasked with advancing nuclear power as a resource capable of major contributions in meeting the energy, environmental, and security needs of the nation. DOE-NE accomplishes this mission by identifying and resolving technical, cost, safety, security, proliferation resistance, and regulatory barriers through research, development, and demonstration.

DOE-NE performs additional mission-related functions that include:

- Engaging (international and domestic) support of the safe, secure, and peaceful use of nuclear energy
- Developing and furnishing nuclear power systems for national security and space exploration applications.

DOE-NE established NGNP specifically to deliver the design, licensing, and R&D needed to accelerate domestic commercialization of gas-cooled reactor technology. This is done using the resources of several DOE national laboratories (INL is the lead DOE laboratory for nuclear energy), multiple U.S. universities, the nuclear industry, international partners, and NRC staff. NGNP, managed by DOE-NE through the INL, has project mission, goals, objectives, and budgets provided according to specifications contained in INL's Project Management System Description document.[5]

2.2 Nuclear Regulatory Commission/Department of Energy Memorandum of Understanding

As earlier noted, the EPAct of 2005 directed the Secretary of Energy and the NRC Chairman to develop a licensing strategy for NGNP and report that strategy back to Congress. On October 12, 2006, DOE-NE entered into a memorandum of understanding (MOU) with NRC to develop a joint strategy. The resulting memorandum addressed neither fiscal matters nor funding obligations, but rather announced the interagency intention to provide a clear and practical roadmap suitable for congressional review and action.

The NRC/DOE MOU called for comprehensive consideration of reactor licensing and budgetary requirements related to NGNP. It also recognized that new analytical tools would be necessary to verify safety performance and that additional R&D is needed to support licensing. Organizational responsibilities, along with guiding principles and processes, were set forth concerning the interaction between NRC and DOE on an agency-to-agency basis.

The MOU identified DOE as responsible for developing and providing the most accurate and current information available on prospective NGNP reactor design activities, as well as technology options. DOE was to sponsor the technology development plans and programs necessary to support the technology options. The INL was designated lead DOE national laboratory for NGNP.

NRC responsibilities included providing information on current regulations and guidance relevant to NGNP reactor design and advanced reactor technology licensing. The MOU recognized NRCs' duty to maintain an independent review capability and evaluate all NGNP licensing issues to assure public interests are preserved.

The MOU also noted shared responsibilities between DOE and NRC. This included identifying and resolving a variety of different factors that affect the viability of the NGNP licensing strategy and defining pathways to address licensing obstacles. Both agencies were obliged to share information with the public in a clear and timely manner, consistent with each agency's existing legal obligation.

2.3 Next Generation Nuclear Plant

2.3.1 Next Generation Nuclear Plant Regulatory Affairs

A primary function of NGNP Regulatory Affairs is coordination with NRC on establishing a viable project licensing approach and supporting schedule. NGNP Regulatory Affairs staff worked with other NGNP team members to identify regulatory and policy issues before license application development and/or NRC granting authorization to load fuel. These interactions, conducted in accord with the DOE/NRC MOU discussed in Section 2.2 and detailed in PLN-3202, "NGNP Licensing Plan,"[6] focused on:

- Requirements and criteria for functional performance of the multi-barrier NGNP design as a radiological barrier
- Approaches for using probabilistic risk assessment to inform the selection of licensing basis events, including establishing special treatment requirements and defense-in-depth requirements
- Allowable dose consequences for the licensing basis event categories
- Developing an acceptable basis for event-specific, mechanistic source terms calculation that includes the siting source term.

Additional NGNP Regulatory Affairs functions included:

- Coordinating all technical and prelicensing interfaces with NRC and environmental/state regulatory agencies
- Transmitting information to NRC staff in a format consistent with applicable interagency agreement(s) and MOU(s) in support of NRC review activities
- Coordinating responses to incoming NRC request for additional information (RAIs)
- Coordinating with NRC to schedule and conduct public and drop-in meetings and teleconferences, as required to advance the licensing process
- Communicating project status and future plans (e.g., responses to NRC regulatory issue summaries) such that NRC review resources could be efficiently assigned and scheduled
- Establishing and maintaining processes for regularly communicating regulatory interface activities with project team members and stakeholders
- Maintaining cognizance over industry activities associated with advanced small modular reactor (SMR) initiatives and developing associated regulatory requirements and guidance.

2.3.2 High-Temperature Gas-Cooled Reactor Vendors and Owners/Operators

NGNP prelicensing activities gained extensive benefit from the design and licensing expertise provided by the three domestic HTGR supplier firms (AREVA, Westinghouse, and General Atomics), an owner/operator organization (Entergy), and an HTGR-technology consulting firm (Technology Insights). Representatives from these organizations comprised the NGNP Licensing Working Group (LWG). In addition, NGNP actively participated in generic SMR industry prelicensing activities to address administrative and technical regulatory issues common to the SMR community. These organizations and their related NGNP activities are also discussed in Section 3.2.2.

3. LICENSING APPROACH

3.1 Next Generation Nuclear Plant Licensing Strategy – Report to Congress

Provisions of Section 644 of the EPAct of 2005 jointly required the Secretary of Energy and the Chairman of the NRC to submit to Congress a licensing strategy for NGNP. The 2008 Report to Congress:

- Described the ways in which NRC needed to adapt its current LWR licensing requirements to accommodate the types of reactors considered for the project
- Described the analytical tools NRC still needed to independently verify the NGNP design and its safety performance
- Described other research or development activities that NRC will need to complete to be prepared to conduct a review of an NGNP license application
- Estimated a budget associated with implementing the licensing strategy.

The strategy report recommended adoption of the 10 CFR 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants,"[7] COLA process as the approach to NGNP licensing. This methodology was judged an expedient means to obtain regulatory approval based on HTGR technology as applied to NGNP. However, an alternate licensing approach (e.g., 10 CFR 50) could also be used as another option and would benefit from the work products and activities completed by the NGNP team (based on a 10 CFR 52 licensing process).

3.2 Next Generation Nuclear Plant Licensing Development Activities

3.2.1 Development of Prelicensing Issues

The NRC licensing process encourages applicants to engage early with NRC staff to identify and resolve policy, regulatory, and technical issues associated with a proposed nuclear facility license. Effective interaction with NRC staff is critical to the NGNP licensing strategy because timely resolution of significant regulatory issues is essential to developing a NGNP license application and plant deployment schedule.

Accordingly, from 2009 through 2011, NGNP submitted to NRC staff a series of white papers that addressed high priority prelicensing issues. The white papers were written to address important topics identified in the NGNP Licensing Plan and are individually discussed in Section 4.

Identifying Priority Issues

An effective pre-application program fully coordinated with NRC is critical to a new reactor licensing approach. Early establishment of plans to resolve complex and interrelated issues eases some of the uncertainties associated with preparation of a COLA, accelerates application review schedules, and enhances the potential chance for success of a technology demonstration plant.

As noted in Section 2.3.1, PLN-3202 identified numerous priority NGNP licensing issues suitable for pre-application discussion with NRC staff. These issues were gathered from a number of sources that included a General Atomics modular high temperature gas-cooled reactor (MHTGR) precedent, the Exelon Pebble Bed Modular Reactor (PBMR) licensing program, the PBMR (Pty) Ltd. U.S. Design Certification program, and various NGNP-sponsored studies. Identified issues were then prioritized based on expected potential impact to overall plant design, ongoing related project activities, licensing strategies, and necessary milestones for project completion. This resulted in a tabular description of each issue that is presented in Appendix A of PLN-3202.

NRC also independently evaluated a broad set of potential policy issues and licensing topics applicable to advanced SMR designs that included modular HTGRs. At the conclusion of the evaluation, NRC developed a general position and issued SECY-10-0034.[8] This SECY identified key areas of focus for both NRC and industry with respect to advanced reactor licensing.

The SECY-10-0034 list of licensing issues aligned well with the priority NGNP topics identified in PLN-3202. Major intersecting issues included topics related to risk informed performance based (RIPB) licensing methods, emergency planning, mechanistic source terms, and a range of similarly related topics.

Pre-application Licensing White Papers

NGNP developed a series of "white papers" to further resolution of some of the most significant modular HTGR technology licensing issues. These documents interfaced with each other to create a basis for soliciting informed decisions from NRC staff on the acceptability of an overall regulatory approach proposed by NGNP. Figure 1 identifies the themes of prospective white papers, along with their relationship to foundational regulatory problems that underlie their purpose. NGNP white papers are discussed in Section 4. (Note: Although all topics listed in Figure 1 are appropriate subject matter for a white paper, limitations in project resources and schedules indicated that only high priority topics currently representing a source of significant licensing uncertainty could be addressed through a NGNP prelicensing white paper. See Appendix A of this report for a complete listing of NGNP white papers and their submission schedule to NRC staff.)

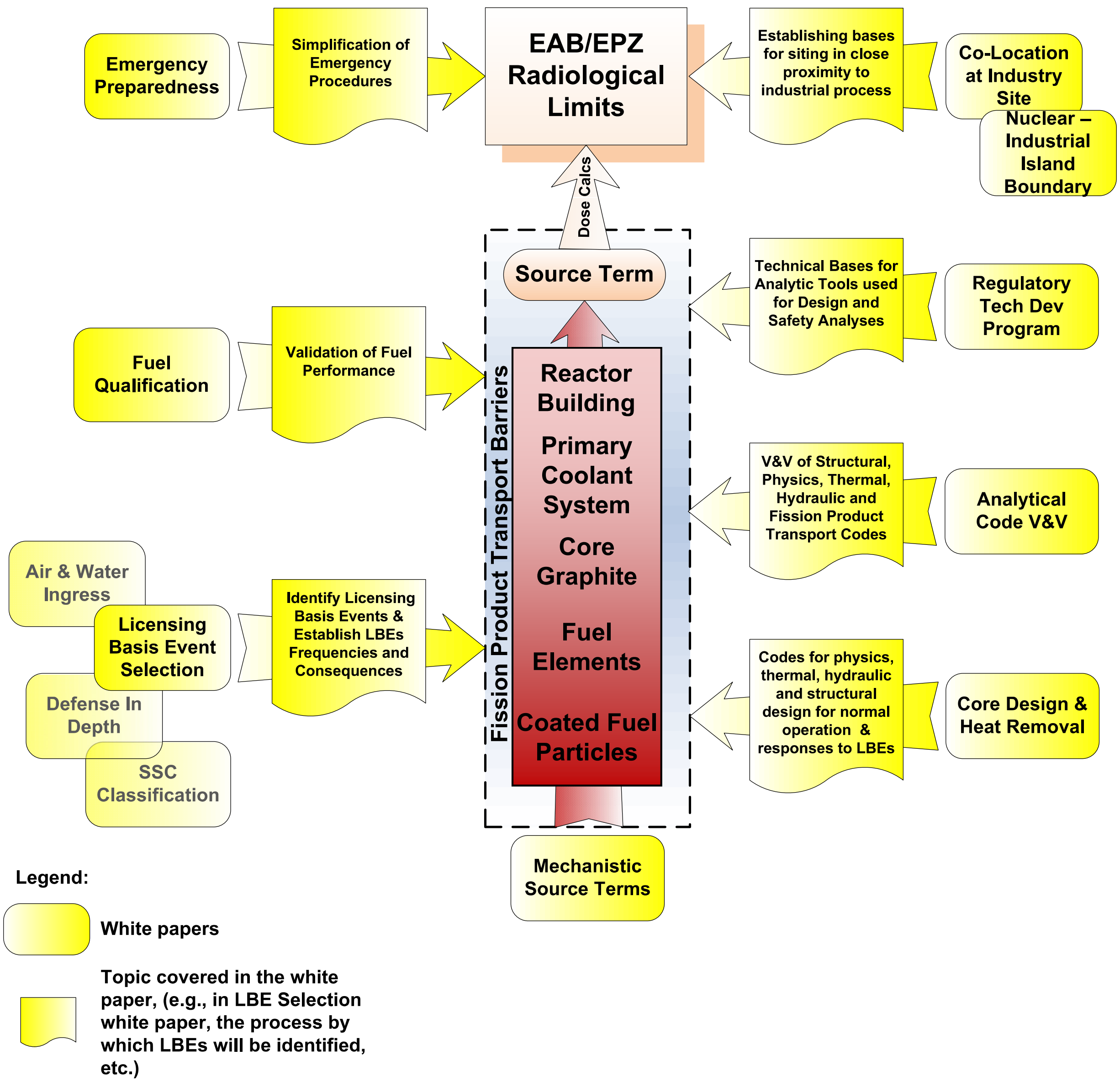

Figure 1. Topical relationship of Next Generation Nuclear Plant prelicensing white papers.

3.2.2 Seminars, Workshops, and Conferences

The following is an outline of other major stakeholder interactions that were coordinated by the NGNP Regulatory Affairs department.

HTGR Training of the NRC Staff

NGNP Regulatory Affairs coordinated development and delivery of a 4-day HTGR technology-training course for NRC staff personnel. Domestic HTGR reactor vendors and other subject matter experts delivered the training on May 24–27, 2010, in Rockville, Maryland. Attendance included about 100 NRC staff and a lesser number of NGNP and DOE personnel. Training instructors consisted of HTGR technology subject matter experts from DOE national laboratories and domestic HTGR vendors.

The HTGR training course emphasized three primary topics: (1) introduction and HTGR overview; (2) HTGR fuel, reactor, and plant design; and (3) HTGR safety analysis. Presentations covered both pebble bed and prismatic reactor core designs. The course was structured to develop NRC staff technical understanding of HTGR technology and thereby increase efficiency on upcoming prelicensing submittal reviews.

NGNP Licensing Working Group

As discussed in Section 2.3.2, NGNP established a Licensing Working Group (LWG). This body acted as an industry advisor and work product generation group for NGNP Regulatory Affairs. Periodic teleconferences were conducted (nominally biweekly) with to keep LWG members apprised of project activities, schedules, and accomplishments, as well as solicit work status updates on project deliverables. Work products developed by individual LWG members were regularly routed for LWG group review and comment prior to release. Other activities included LWG meetings to discuss specific work products such as NGNP white papers and the information delivered to NRC staff and the NRC's Advisory Committee for Reactor Safeguards (ACRS).

Industry Activities and Relationships

Over the course of NGNP, Regulatory Affairs personnel become involved in generic NRC and nuclear industry initiatives associated with SMR technology licensing. Because many SMR regulatory issues draw parallel to similar challenges in HTGR technology, coordination was maintained with various groups interested in furthering new SMR technologies.

In late 2009, the Nuclear Energy Institute (NEI) and the American Nuclear Society (ANS) initiated generic small- and medium-sized reactor activities to address legal, administrative, and technical regulatory issues common to the SMR community. Many of these activities directly related to important NGNP regulatory policy concerns. To address continuity between the different initiatives, NGNP Regulatory Affairs staff became active in the NEI SMR licensing task force. Other task force participants included commercial utilities, reactor vendors, and industry partners with interests in SMR deployment. NRC developed policies and approaches for SMR applications (with input from NEI) that provided valuable insights to NGNP concerning development of a robust licensing framework for modular HTGR applications.

The public meetings held by NRC and supported by NGNP staff are listed in Table 1. This list does not include public meetings or formal interactions with NRC that specifically targeted NGNP documents (like NGNP white papers) and related NGNP prelicensing discussions; those interactions are described in Section 4.

Table 1. Nuclear Regulatory Commission/industry public meeting participation.

Meeting Date	Topic
February 3–4, 2010	NRC Workshop on Licensing Processes and Procedures for Advanced Reactors
March 9–11, 2010	Annual NRC Regulatory Information Conference
April 6, 2010	NRC Public Meeting on New Reactor Licensing
April 13, 2010	NRC Public Meeting on Issues Affecting New Reactors
July 28, 2010	NRC SMR Workshop
September 22–23, 2010	NRC SMR Workshop
December 16, 2010	NRC Public Meeting on SMRs
March 8–10, 2011	Annual NRC Regulatory Information Conference

Table-1. (continued).

Meeting Date	Topic
March 11–16, 2011	NRC Public Meeting on High-Temperature Reactor Dust Issues
April 20, 2011	NRC Public Meeting on Probabilistic Risk Assessment
June 15, 2011	NRC Public Meeting on SMR Issues
August 10, 2011	NRC Public Meeting on SMR Multi-Module Plant Licensing
September 7, 2011	NRC Public Meeting on SMR Risk Insights
October 4, 2011	NRC Public Meeting on SMR Issues
December 15, 2011	NRC Public Meeting on SMR Issues
January 24, 2012	NRC Public Meeting on SMR Issues
February 28, 2012	NRC Public Meeting on Risk-Informed Licensing Framework
March 13–14, 2012	Annual NRC Regulatory Information Conference
April 5, 2012	NRC Public Meeting on SMR Policy Issues
July 19, 2012	NRC Public Meeting on the NuScale Risk-Informed Licensing Approach
August 22, 2012	NRC/FEMA Public Meeting on Changes to Emergency Planning
September 18, 2012	NRC Public Meeting on the Risk-Informed Licensing Approach for New Reactors
October 16, 2012	NRC Public Meeting on Implementation of Emergency Planning Recommendation of the Fukushima Near-Term Task Force
October 17, 2012	NRC Public meeting on Risk-Informed Applications for New Reactors
October 17, 2012	NRC Public Meeting on SMR Issues
December 13, 2012	NRC Public Meeting on SMR Issues
March 12-14, 2013	Annual NRC Regulatory Information Conference

To facilitate consistent planning for staff resource scheduling in future licensing submittals, the NRC issues Regulatory Issues Summaries (RIS) to industry. The RIS solicits voluntary information regarding anticipated reactor licensing actions that rely on NRC resources. Accordingly, NGNP submitted to NRC a series of voluntary responses to Regulatory Issues Summaries.[9,10,11,12]

NGNP engineering personnel were directly involved in several initiatives related to the development of new American Society of Mechanical Engineers (ASME) code and standards for HTGRs. NGNP engineering staff participated in the development of ANS Standard 53.1, "National Safety Criteria and Safety Design Process for Modular Helium-Cooled Reactor Plants."[13]

Other industry activities in which NGNP participated included supporting annual Very High-Temperature Reactor (VHTR) R&D Technical Review Meetings and related conferences, ANS meetings on generic SMR issues, NEI SMR task force meetings, DOE-NE R&D meetings, and International Atomic Energy Agency meetings on the advancement of HTGR technology.

3.2.3 Next Generation Nuclear Plant Site Hazards Assessment

As noted earlier, benefits in applying HTGR technology include elimination of greenhouse gas emissions resulting from use of coal, natural gas and waste gas by industrial facilities. Realized benefits also include enhanced long-term security of the energy supply and long-term stability in the price of the energy. The high temperature operation of the HTGR can achieve much higher net generation efficiencies (40% to >50% depending on the power conversion system deployed) than current light water reactor technologies (~30%). The modularity of the HTGR nuclear heat supply system also provides flexibility in plant sizing and scheduling reactor module build-out at a multi-module plant. Modular installations can also correspond with collocated facility energy demand growth and retirement of other sources of heat.

NGNP conducted field assessments of typical site hazards to identify, evaluate, and catalogue physical hazards, environmental characteristics, and overall constraints relevant to planning, constructing, and operating a modular HTGR facility in a process heat supply setting. Field inspections were performed at two different U.S. locations situated close to large industrial facilities. Assessments were documented so that future HTGR design and licensing decisions may be better informed as to the presence and significance of conditions likely to confront prospective license applicants during initial deployment of a commercial modular HTGR.

Objectives and Locations Assessed

Objectives of NGNP Site Hazard Assessments consisted of:

1. Identifying and initial screening of the potential challenges and constraints that may typically exist at an industrial site that must be considered during nuclear reactor design and licensing processes
2. Providing assurance that HTGR technology can be deployed at a variety of sites for a range of applications
3. Description of actions that might be undertaken to mitigate impacts of surrounding hazards
4. Providing additional key insights to inform the plant design process.

NGNP site hazard assessments examined not only external risks to the reactor nuclear island based on nominal NRC site evaluation criteria, but also the reciprocal risks posed to adjacent industrial activities from a collocated HTGR.

Evaluations began by targeting acquisition of hazard information for “representative classes” of likely industrial energy users in a demonstration HTGR deployment. Multiple locations within the United States were considered and included settings near existing LWR nuclear power stations, “brownfield” sites that previously hosted industrial activities, and relatively undisturbed “greenfield” areas. Two geographical locations typical of initial HTGR deployment were identified. Multiple discrete sites at each location were examined to assess environments ranging from characteristic greenfield conditions to significantly disturbed industrial settings.

The first study was conducted at an undisclosed location adjacent to a deepwater port in a subtropical U.S. coastal environment. Identified as Site 1 to preserve confidentiality, this location encompassed four separate parcels of flat land of varying sizes and distances from likely user processes of HTGR energy.[14] The other location (Site 2) consisted of four relatively undisturbed flat parcels along the Mississippi River about 25 miles northwest of New Orleans, LA.[15] All Site 2 parcels were proximal to an existing industrial park and an operational LWR nuclear power plant.

Analysis Methodology

Assessments were performed according to NGNP-LIC-ETR-RPT-0001, "Procedure for Site Hazards Evaluation and Impact Assessment."[16] The procedure was written by NGNP and identified a large number of characteristics important in determining reactor site suitability. These characteristics were grouped according to regulatory concern (e.g., health and safety, environmental, sociological) and other considerations (e.g., land availability, security, constructability, and contamination hazards). Guidance for documenting site features, local characteristics, and the sources of evaluative criteria used during the assessment was defined. Additional hazards and constraints deemed pertinent to the construction and operation of a modular HTGR that were not listed in the procedure, as well as factors with potential implications to adjacent populations, infrastructures, and the local environment, were assessed using professional judgment.

The individual sites at each of the two locations were assessed in terms of being acceptable, challenged, or unsuitable to reactor siting with respect to specific characteristics. Templates for each characteristic (or group of characteristics, where appropriate) guided assessors in the acquisition of data and deriving professional judgments consistent with the reasoning behind reactor site acceptance criteria. All collected information was documented and archived for future reference.

It is important to note that preliminary and final NGNP design details were unavailable to support these assessments. Consequently, important elements of plant parameter information had to be presumed during field evaluations. Plant parameter envelope (PPE) information such as bounding water use requirements, radiological accident source terms, and foundation embedment depths, was gathered from the General Atomics design for a Gas-Turbine, Modular Helium Reactor.[17] It was also assumed that the basic NGNP facility design consisted of a four-reactor module HTGR nuclear plant (2,000-2,400 MW[t]) capable of co-generating process steam, electricity for general use, and hot gas that could be transported directly to an industrial process customer.

Conclusions

Conclusions of the NGNP Site Hazards Assessment do not infer or represent a preliminary licensing action at either analyzed location. Should owners of Site 1 or 2 make a future decision to pursue a modular HTGR license at one of the examined land parcels, additional evaluations and confirmatory studies will be necessary in a context of final HTGR design and done in conjunction with a comprehensive site investigation process.

The assessments concluded that locations similar to those found in Sites 1 and2 generally offered discrete land parcels suitable for constructing and operating a collocated modular HTGR plant near an industrial energy user facility. However, the employed PPE assumptions suggested certain parcels would be challenged with respect to a nuclear facility installation. Contingent on facility configuration, issues like physical security standoff distance and a construction material lay-down area would need thorough evaluations before installing a HTGR module. Additional issues include (but are not limited to):

- **Seismic/Hydrologic/Geotechnical:** All evaluated sites were located in regions with good geological characterization information and low seismicity; no undue risks attributable to potential ground acceleration were noted. However, excavation to a depth of 140 feet (presumed for the HTGR PPE) will likely encounter construction and operational hurdles in terms of groundwater dewatering, ground settlement, and surrounding surface subsidence. Engineering provisions for permanent groundwater dewatering and/or high hydrostatic loads on subsurface HTGR structures like the basemat may be necessary. Depending on water demands of the HTGR facility, there may be issues regarding sufficient fresh water availability to support year-round reactor operations. Salt dome mines in coastal regions can pose a unique hazard not only because of ground surface subsidence but also because they might be intermittently used to store materials that pose a hazard to a nuclear facility.

- **Flooding Protection:** Surficial flood risks could require HTGR designers to incorporate substantial flood protection measures that must be coordinated with other regional entities. Such measures include installation and/or increased maintenance of local levees shared with adjacent industrial facilities and/or communities. Installation of water-tight doors and external entry points to HTGR safety-related structures that are located well above nominal surface elevations and base flood events may also be necessary.
- **Nearby Hazards:** Multiple inhalation, explosive, and flammability hazards may exist in proximity to a collocated industrial facility. These risks could require mitigation through HTGR design rather than avoidance due to the need for locating the nuclear island relatively near energy user processes. Some of those industrial heat energy use processes may involve materials that pose risks to HTGR operations. Designers of a collocated HTGR must consider control room habitability and address the potential of corrosives, explosives, and flammable materials on safety-related structures. There may also be risks from environmental contamination migrations in the area via natural media transport mechanisms.
- **Constructability:** The HTGR facility "footprint" may be too large for desirable sites close to heat use processes. Some heat applications may require design solutions that ensure heat transfer losses over considerable distances remain within limits for the target application. Also of concern is temporary dewatering of an excavation to facilitate construction. Extensive mitigation measures may be necessary in high groundwater locations to ensure adjacent structures are protected from damage through differential settlement during construction.

Parcels at Sites 1 and 2 are broadly representative of the general hazards and challenges expected with initial NGNP deployment at an industrial setting. Reactor designers, license applicants, and interested stakeholders are encouraged to become familiar with the NGNP Site Hazards Assessments and use that information during future design and project evaluations.

3.2.4 Next Generation Nuclear Plant Regulatory Gap Analysis

The NGNP Regulatory Gap Analysis (RGA)[18] examined NRC requirements and guidance positions effective as of June 2010 as they pertained to licensing a generic modular HTGR. The activity examined several thousand individual regulatory elements and identified dozens of specific items and topics that must be further evaluated and reconciled prior to NRC acceptance of an HTGR COLA for review. A summary of NGNP RGA study findings is provided below.

Background and Purpose

Regulations set forth in Title 10 of the Code of Federal Regulations (CFR), along with related implementation guidance that clarify how those regulations can be satisfied, provide license applicants and NRC reviewers the information necessary to develop and review a license application. However, many of the regulations and guidance positions exhibit a strong orientation toward large LWR power plant technology; non-LWR technologies that use alternative means to achieve performance and safety goals may encounter great uncertainty when writing a COLA because key LWR requirements are not applicable. Because some important HTGR structures, systems and components (SSCs) have no corollary to traditional LWR systems, this ambiguity required evaluation. A systematic evaluation of NRC nuclear reactor licensing regulations and guidance was performed using design attributes of a generic HTGR design to identify specific regulatory "gaps" that may exist.

The NGNP RGA was neither scoped nor performed to support a specific HTGR COLA or proprietary modular HTGR design *per se*. Instead, the study focused on facilitating creation of a robust licensing framework that could accommodate the unique design elements, features, and functions of potential NGNP modular HTGR designs.

Analysis Methodology

A team of nuclear power plant design engineers and regulatory analysts knowledgeable in HTGR design and experienced in NRC power reactor licensing performed the NGNP RGA study in accordance with requirements set forth in NGNP-LIC-ETR-PROC-001, "Procedure for Performing the Regulatory Gap Analysis."[19] The procedure defined regulatory review parameters for 18 key bodies of NRC regulation and associated guidance (such as NUREG-0800[20]) and resulted in the examination of nearly 2,600 individual regulatory positions.

Regulatory requirements and associated guidance statements were "binned" into one of three categories during the evaluation. *Applicable* meant the item was relevant to HTGRs and applicable without modification or clarification to existing language. *Partially Applicable* indicated the underlying principle of the statement was applicable to HTGRs but the statement could not be fully applied as written. *Not Applicable* designated positions with no discernible relevance to the modular HTGR design.

The NGNP RGA focused on determining applicability of individual regulatory positions to the standard modular HTGR design and describing likely issues future applicants might face if those positions were relied upon during licensing. No attempt was made to resolve discovered regulatory uncertainties or insufficiencies (i.e., regulatory gaps) during the course of evaluation. However, resolution of many of the documented gaps has already begun with NGNP prelicensing white paper submittals described in Section 4. Remaining gaps need resolution by appropriate industry trade associations, organizations responsible for establishing codes and standards, and applicants in conjunction with the NRC.

The principal design example employed during the NGNP RGA was the DOE-sponsored MHTGR prismatic-block reactor core design that underwent NRC pre-application review in the 1980s and early 1990s.[21,22] This review resulted in an NRC Safety Evaluation Report.[23,24] Together, these documents provided analysts the most comprehensive source of modular HTGR design information then available to the public. The documents were examined whenever design information was required to support a determination of potential regulatory applicability. Supplemental information was also gathered from NRC public information databases for design and licensing insights related to a pebble bed design certification (DC) effort performed in 2005. Results of the NGNP RGA represented both pebble bed and prismatic block-type approaches to modular HTGR design.

Interpretation of the underlying regulatory intentions for regulatory positions was frequently required during the conduct of the NGNP RGA. Translating LWR-oriented terms associated with certain regulatory statements into relevant HTGR technology conditions required interpretations that sometimes affected large portions of the overall regulatory framework; See Section 2.2 of INL/EXT-11-23216[18] for further discussion on the important topic of adapting LWR regulatory requirements to HTGR technology.

Conclusion

Of the 2,589 regulatory and guidance positions evaluated for applicability, 1,735 were determined to be applicable to modular HTGRs as written, 463 were partially applicable, and 391 were deemed not applicable to modular HTGR technology. Of the positions determined to be partially applicable, 108 were identified for follow-up consideration by applicants and regulators. Fifteen of the 108 items were regulations while the remainder consisted of guidance contained in either NUREG-0800 or various NRC Regulatory Guides (RG).

Along with locating gaps in regulation and guidance, analysts also noted the nature of the gap. Most of the 108 items recommended for further consideration addressed a concern that is consigned to one or more of the following categories:

- Revision of existing text to move away from terms specific to pressurized water reactor or boiling water reactor technology-specific terms and provide a more technology-neutral perspective, while retaining the underlying safety basis for the requirement or guidance
- Requirements associated with LWR event sequences or phenomena or lists of radionuclides specific to LWR technology
- Allow for reporting and financial thresholds other than that provided in LWR-specific formulations.

Fourteen regulatory positions were not specifically evaluated due to the absence of adequate HTGR design information. These encompassed design decisions such as the safety status of emergency power and instrument air, the use of protective surface coatings, and requirements for reactor building leak tightness testing. The regulatory status of such issues are design decisions to be resolved during COLA development.

Lastly, the RGA identified a set of important topics unique to HTGRs that have no clear standing or counterpart within the current LWR-oriented regulatory structure. These issues were noted as extensively treated in current regulations and guidance (as they relate to LWRs) but do so in ways that offer no comparable application to HTGRs. Hence, issues that might be termed “topical” regulatory gaps include:

- HTGR fuel, design, and qualification
- High-temperature ceramic materials (e.g., graphite), composites, reactor internal structures, and components design, manufacturing, inspection, and testing
- Functional containment of radionuclide releases from the HTGR multiple barrier system
- Risk metric alternatives to core damage frequency and large early release frequency
- Guidance concerning use of passive safety features
- Helium leakage and leak detection guidance
- Safety classification for HTGR SSCs
- HTGR accident analysis guidance.

NGNP initiated prelicensing actions that establish approaches to resolving many of these “topical” gaps; refer to Section 4 for further details.

3.2.5 High-Temperature Gas-Cooled Reactor Combined License Application Content Guide Development

RG 1.206, “Combined License Applications for Nuclear Power Plants” (LWR Edition),[25] provides guidance on format and content to writers of LWR COLAs. NGNP started developing guidance in the same format as RG 1.206 to provide writers of a HTGR COLA similar levels of guidance and increase the surety by which a NGNP COLA can be appropriately formatted and written. The following outlines the status of this unfinished effort.

Background and Purpose

Large portions of RG 1.206 guidance are technology-neutral and can be applied to both LWR and non-LWR technologies. However, other portions are very specific to LWRs and do not support alternative reactor technologies like the HTGR, as written.[26] This is particularly true for basic technology descriptions and novel plant SSCs that have no LWR equivalent.

Part I of RG 1.206 (LWR Edition), "Standard Format and Content of Combined License Application," is composed of 19 chapters, each corresponding to an equivalent chapter of a nuclear plants' final safety analysis report (FSAR). Support to modular HTGR licensing means each chapter of RG 1.206 requires evaluation and amendment as necessary to reflect provisions and approaches applicable to the HTGR FSAR. NGNP staff initiated a revision to RG 1.206 (LWR Edition, Part I) language to incorporate key understandings about the generic HTGR design. Once completed, the new COLA Content Guide (i.e., Content Guide) is to be submitted to NRC for review and endorsement.

Development Methodology

Of the 19 chapters of Part I, RG 1.206 (LWR Edition) requiring conversion to a HTGR Content Guide, six were chosen for initial analysis and revision. The chapters were selected based on the following criteria:

- Scope of text changes needed to incorporate HTGR technology descriptions and the extent to which fundamental HTGR system attributes are absent from or not directly represented in the LWR edition of RG 1.206
- The level of modular HTGR design information available in the public domain to support HTGR Content Guide development
- Need to identify and discriminate between elements important to HTGR safety as opposed to the LWR technology currently presumed in RG 1.206
- Opportunities to incorporate a risk-informed, performance-based licensing approach into the Content Guide
- Opportunities to establish how LWR licensing guidance can be extended and adapted to become modular HTGR technology guidance.

By also considering the opportunity to incorporate basic HTGR technology descriptions and safety approaches within a RIPB licensing framework, revisions were made in the following chapters:

- Chapter 1, Introduction and General Description of the Plant
- Chapter 3, Design of Structures, Systems, Components, and Equipment
- Chapter 4, Reactor System
- Chapter 5, Helium Pressure Boundary and Connecting Systems
- Chapter 6, Engineered Safety Features
- Chapter 9, Auxiliary Systems
- Chapter 15, Transient and Accident Analysis (Table of Contents only).

These chapters encompassed some of the most extensive and challenging adaptations to RG 1.206 when creating an HTGR Content Guide. They also defined many key HTGR design features and safety functions referenced elsewhere in the guide.

Revisions started by replacing LWR technology descriptions with HTGR descriptions, adding language appropriate to the design and function of basic HTGR system elements, and amending or removing restrictive or irrelevant LWR-oriented statements such that a more technology-neutral, risk-informed, performance-based approach could be added. Results from the NGNP RGA (see Section 3.2.4) were incorporated as was HTGR-specific guidance from previous licensing actions. Although the original RG 1.206 chapter titles were sometimes modified to better reflect HTGR technology, the original document structure and configuration of RG 1.206 was retained as much as possible.

Extensive discussions were conducted with NRC staff in connection with NGNP white papers that supported Content Guide development. These interactions included submission and feedback on NGNP white papers, interactions involving NRC requests for additional information related to the white papers, and a series of public meetings that culminated in issuance of NRC position papers. The draft HTGR Content Guide reflected results of these interactions to the extent they were available in August 2012.

General Design Criteria/Principal Design Criteria

Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities,"[27] provide general design criteria (GDC) for nuclear power plants. The GDC establish minimum specific requirements for the principal design criteria (PDC) of water-cooled nuclear power plants. They are also generally applicable to other types of nuclear power units as guidance in establishing PDCs for such units. The PDC define necessary design, fabrication, construction, testing, and performance requirements for structures, systems, and components important to safety. Structures, systems, and components built and operated in conformance to applicable design criteria provide reasonable assurance that the facility will not pose undue risk to the health and safety of the public.

Under the provisions of 10 CFR 52.47, 52.79, 52.137, and 52.157, an application for a design certification, combined license, design approval, or manufacturing license, respectively, must include the PDC for the proposed facility. RG 1.206 (LWR Edition)[25] and the NRC's NUREG-0800, "Standard Review Plan,"[20] extensively rely on GDC requirements for LWR designs. Accordingly, developing the HTGR COLA Content Guide made it necessary to identify key PDC content for the modular HTGR.

Because GDCs contain regulatory requirements that guide important safety attributes of reactor design and operation, a thorough understanding of applicable GDCs is prerequisite to developing meaningful guidance. Thus, an ability to reference a concise set of design criteria applicable to the modular HTGR safety design is mandatory when formulating HTGR Content Guide guidance.

As noted in Section 3.2.4, much of the current GDC guidance is technology-neutral and applicable to modular HTGR technology without modification. However, some LWR-oriented criteria require adaptation before they can be applied or may not be relevant while other important design safety characteristics unique to the technology are not addressed in 10 CFR 50 Appendix A GDCs and must be established.

The text of each 10 CFR 50 Appendix A GDC was evaluated for applicability during the NGNP RGA and again during HTGR Content Guide development. Some criteria were adapted to support HTGR technology attributes and additional safety design criteria not provided in Appendix A were proposed to create a complete set of principal design criteria compatible with the NGNP design concept. Preserving the underlying safety intent of each 10 CFR 50 Appendix A GDC in the corresponding design-specific PDC was a central concern during this effort.

The absence of clear and relevant safety design criteria appropriate to non-LWR technology is a source of significant uncertainty throughout the entire advanced reactor community. Recently, this issue became the subject of a DOE study focused on developing clear and robust guidance concerning Appendix A GDC application to non-LWR design decisions. The preliminary HTGR PDCs developed by NGNP were used as a key technical input to the DOE advanced reactor design criteria guidance development effort. Results of the DOE advanced reactor design criteria study were released in late 2014.[28] Study findings and recommendations were then submitted to NRC staff along with a request that the report be reviewed and endorsed as regulatory guidance appropriate for use when establishing advanced reactor technology-specific principle design criteria.

Current Status

In August 2012, changes in programmatic direction resulted in curtailing HTGR Content Guide development efforts. Content Guide chapters drafted up to that time were: 1, 3, 4, 5, 6, and 9. Chapter 15 was also modified insofar as the Table of Contents was revised but not the text; this particular chapter deals with nuclear facility event selection and analysis of facility response to those events. Because essential elements of the RIPB licensing framework were still under consideration by NRC staff at the time Content Guide development was suspended, no changes could be incorporated into Chapter 15 text.

None of the HTGR Content Guide drafted thus far has undergone review by NRC staff. However, technical representatives from the NGNP LWG assisted in drafting and peer review of revised Content Guide chapters.

All 19 chapters of RG 1.206 (LWR Edition), as well as data from the NGNP RGA and the Content Guide text generated as of August 2012, were entered into an *Access* computer database. This database was constructed such that NRC acceptance requirements as stated in of NUREG-0800 could be incorporated into the Content Guide should it be deemed necessary to do so in the future. The database and reference documents cited in the draft Content Guide are available from the INL.

Further extrapolation of RG 1.206 (LWR Edition) contents into a functional HTGR Content Guide is still necessary. Although six chapters were revised, these chapters still require review and subsequent update concurrent to ongoing progress in developing the advanced reactor regulatory framework and the final NGNP design.

NGNP Regulatory Affairs staff recommends that work resume on the HTGR Content Guide. Doing so would benefit writers and reviewers of HTGR COLAs with similar guidance to that currently available to LWR COLA developers. Without such NRC-endorsed guidance, developing an HTGR license application will remain far more subjective and iterative than necessary.

4. KEY PRELICENSING FRAMEWORK TOPICS

In a June 2011 letter to DOE Secretary Chu,[29] the DOE Nuclear Energy Advisory Committee (NEAC) recommended (in part) that DOE continue to engage NRC staff on prelicensing activities essential to NGNP deployment and ensure that an appropriate commercial regulatory framework is established for modular HTGR reactor technology. The Secretary of Energy adopted this recommendation and in October 2011 sent a letter to Congress[4] confirming NGNP will continue near-term development effort on the NGNP licensing framework. This development would include interactions with the NRC.

A February 2012 letter[30] from the NRC to DOE identified four areas critical to establishing an NGNP licensing framework. These topics were chosen because they represented areas of great regulatory uncertainty and significantly influence NGNP licensing success. The four key topics were:

- Containment functional performance
- Licensing basis event (LBE) selection
- Source terms
- Emergency planning.

Early resolution of questions related to these topics is critical to formulating elements of the licensing framework that define COLA development activities and enable effective NRC staff review. These topics were also identified by the NRC in SECY-10-0034, "Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs,"[8] as key issues for near-term resolution.

4.1 Approach to Resolution

The four key topics support NGNP's definition of defense-in-depth (DID). Defense-in-depth refers to a safety philosophy based on multiple lines of defense, application of safety margins, and compensatory measures applied to the design, construction, operation, maintenance, and regulation of a nuclear plant.

Relying on information and outcome objectives contained in NGNP white papers dealing with fuel qualification, mechanistic source terms, emergency planning, licensing basis event selection and relevant elements of defense-in-depth, SSC safety classification, and use of plant probabilistic risk assessment (PRA) white papers, discussions were held with NRC staff on the four topics. Supplemental information was gathered from preliminary NRC staff assessments of the white papers and NGNP responses to NRC requests for additional information (RAI).

In a July 6, 2012 letter,[31] NGNP requested that NRC develop formal staff positions concerning the four topical areas consistent with ongoing NGNP prelicensing efforts. While specific NGNP positions regarding the four topical areas were contained to varying degrees in several NGNP white papers, NGNP and NRC staff initiated a public dialogue dedicated to further develop the specific goals contained in the July 6, 2012 letter. NGNP compiled a list of specific discussion items related to these goals in a series of informational worksheets; see the "NGNP Issue Resolution Worksheet Items" provided in Appendix B for further details.

The ensuing regulatory interactions led to three meetings before the ACRS Future Plant Designs Subcommittee in January, April, and May 2013. The final meeting was held before the ACRS Full Committee and produced written recommendations that were forwarded to the NRC Executive Director for Operations.[32]

4.1.1 Containment Functional Performance

The high-temperature radionuclide retention capability of the tri-structural isotropic (TRISO) coated fuel particle is a key safety element in HTGR design and essential to the modular HTGR licensing approach. The HTGR functional containment concept consists of design selections that, when taken together, ensure off-site doses resulting from LBEs do not exceed the Environmental Policy Act (EPA) Protective Action Guides (PAG) at the site Exclusion Area Boundary (EAB). Principle functional containment barriers in this concept are fuel kernels, fuel particle coatings, graphite matrix, the helium pressure boundary, and the reactor building. Functional containment performance is also supported by multiple inherent and passive design features such as low power density, negative temperature coefficient, slender core geometry, and a passively-cooled reactor vessel which keeps fuel within defined limits under operating and accident conditions. Functional containment is also consistent with the concept of DID.

On July 6, 2012, NGNP submitted a letter to NRC clarifying specific topics for requested NRC staff positions. Position Request 1.b of that letter asked for evaluations that provide for options regarding functional containment performance standards as requested by the Commission in the March 8, 2003 staff requirements memorandum (SRM) to SECY-03-0047, "Policy Issues Related to Licensing Non-Light Water Reactor Designs."[33] This was also discussed 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."[34] (See Appendix B of this report for further information.)

In ML14174A774,[48] the staff acknowledged that the Commission already found the concept of functional containment to be generally acceptable (as indicated in the SRMs to SECY-93-092 and SECY-03-0047). The staff also agreed with NGNP that the proposed upper tier performance standard for functional containment should be to ensure the integrity of the fuel particle barriers (i.e., the kernel and coatings of the TRISO-coated fuel particles) rather than allow significant fuel particle failures and extensively rely on other mechanistic barriers (e.g., the helium pressure boundary and the reactor building).

In addition to the functional containment performance standards already accepted by the staff in SECY-05-0006, ML14174A774 also noted that the NGNP standard should be characterized by:

- Ensuring radionuclide retention within fuel during normal operation with relatively low inventory released into the helium pressure boundary
- Limiting radionuclide releases to the environs to meet the onsite and offsite radionuclide dose acceptance criteria (i.e., 10 CFR 50.34 and EPA PAGs) at the EAB with margin for a wide spectrum of off-normal event sequences
- Maintaining the capability to establish controlled leakage and controlled release of delayed accident source term radionuclides.

Final acceptance of the proposed NGNP approach to functional containment for the modular HTGR concept, with its emphasis on passive safety features and radionuclide retention within the fuel over a broad spectrum of off-normal conditions, necessitates that required fuel particle performance capabilities be demonstrated with a high degree of certainty.

Fuel Qualification White Paper

Purpose

The purpose of the NGNP Fuel Qualification white paper[35] is to:

- Identify existing regulations, regulatory guidance, and licensing precedents relative to the qualification of fuel for NGNP
- Summarize existing international experience, data, and analysis methods regarding coated-particle fuel performance

- Review reactor and fuel designs and resulting fuel service conditions and performance requirements
- Describe planned fuel fabrication, irradiation, testing activities
- Obtain feedback from the NRC staff on the proposed approach to qualify the fuel.

The document considered both pebble bed and prismatic HTGR fuel alternatives.

Outcome Objectives

NGNP requested that NRC staff confirm that plans presented in the white paper were generally acceptable and identify additional information and/or testing necessary to demonstrate adequacy of NGNP fuel performance. Specific issues for NRC staff consideration consisted of:

- Confirming that plans for qualifying UO_2 pebble fuel-type are generally acceptable, including:

  A. Utilizing German data for normal operation irradiation and transient/accident heat-up conditions

  B. Performing additional confirmatory irradiation and safety tests on fuel manufactured at a qualified facility to:

     1. Statistically strengthen the performance database
     2. Demonstrate that the fuel performance is equivalent to or better than the German fuel upon which the UO_2 pebble fuel design is based
- Verifying plans that establish the qualification of UCO prismatic fuel-type are generally acceptable based on the NGNP/Advanced Gas Reactor (AGR) Fuel Program
- Providing feedback on other activities and information as may be necessary to support qualification of both pebble-bed UO_2 and prismatic UCO fuels.

Requested NRC Staff Positions

On July 6, 2012, NGNP submitted a letter[31] to the NRC identifying individual areas where staff positions are sought. Relative to fuel qualification, NGNP requested (position request 1.a.) that NRC:

"*Confirm plans being implemented by the Advanced Gas Reactor Fuel Development and Qualification Program are generally acceptable and provide reasonable assurance of the capability of coated particle fuel to retain fission products in a controlled and predictable manner. Identify any additional information or testing needed to provide adequate assurance of this capability, if required.*"

Further details on this request are contained in Appendix B.

Interactions and Outcomes

NGNP submitted the Fuel Qualification White Paper to NRC on July 21, 2010.[36] An overview of the document was presented to NRC staff on September 2, 2010 (ML102590247).

On May 3, 2011, NGNP submitted a letter to NRC[37] noting cancellation of the Pebble Bed Demonstration Power Plant Project in South Africa. Because much of the NGNP fuel qualification strategy discussed in the white paper related to qualification of pebble bed fuel, a request was made that these elements be withheld from immediate NRC review.

NRC chose to review the Fuel Qualification White Paper and the Mechanistic Source Terms White Paper[38] as a single review package. Based on the combined review, NRC requested additional fuel qualification information in the form of 52 RAIs in NRC Letter No. 002.[39] NGNP responded to these RAIs in correspondence dated August 10, 2011.[40]

The NRC requested additional information and clarification in NRC Letter No. 003.[41] NRC issued this letter with 82 RAIs related to NGNP fuel qualification. RAI responses were provided in a letter dated September 21, 2011.[42] A public meeting followed with NRC staff on October 19, 2011, to discuss issues associated with NGNP responses to the fuel qualification and mechanistic source terms RAIs. Handouts for this meeting are available in ADAMS (ML113000320).[43]

NRC developed and transmitted a staff working group draft assessment report entitled, "Assessment of White Paper Submittals on Fuel Qualification and Mechanistic Source Terms."[44] Items requiring follow-up that were identified in this report were tabulated in a spreadsheet to track progress on discussion and resolution. Additional public meetings were held on April 17, 2012,[45] and July 24, 2012,[46] to further address outstanding issues.

A briefing was provided by NGNP to the ACRS Future Plant Designs Subcommittee on January 17, 2013.[47] This briefing included discussion of the fuel qualification program. The NRC staff then drafted updated proposed positions on the adequacy of the fuel qualification program on March 11, 2013 (ML13002A168) and briefed the ACRS subcommittee on April 9, 2013. This was followed by a joint NGNP/ NRC presentation to the ACRS Full Committee on May 9, 2013. The ACRS responded by issuing a letter summarizing the committee's findings relative to the fuel qualification program and other NGNP prelicensing review topics on May 15, 2013.[32]

Outcomes of the regulatory interactions related to the NGNP Fuel Qualification White Paper are documented in ML14174A845, "Assessment of White Paper Submittals on Fuel Qualification and Mechanistic Source Terms (Revision 1)",[48] Enclosure 2. In it, the NRC staff generally endorsed the NGNP approach to fuel qualification as proposed. However, the staff identified one area of concern that may require supplement to the currently planned fuel qualification program.

A question remained regarding the extent to which irradiation testing in water-cooled materials test reactors such as the INL's Advanced Test Reactor (ATR) can provide an adequately prototypical environment for HTGR fuel. A concern existed that the neutron spectrum in an HTGR is "harder" than that in water-cooled reactors and the composition of the test capsules irradiated in the program do not result in a prototypical number of plutonium fissions in the test fuel. This, in turn, caused the staff to question whether production of fission products (such as silver and palladium, both of which have higher fission yields from plutonium fission and can affect fuel particle performance) is high enough to ensure an understanding of their effects on fuel performance.

Although NGNP provided analyses information [49,50] to support a position that the proposed fuel irradiation program adequately addresses this issue, NRC staff concerns remain. The issue could be addressed by conducting a proof test that includes post-irradiation safety testing of fuel from the production-scale fabrication of the initial core of the first reactor. NRC staff has indicated that such a proof test would address uncertainties regarding the process of scaling up the fuel fabrication process from laboratory to engineering to production scale. However, NGNP has not yet committed to perform such a proof test.

Many of the outstanding items identified in the latest NRC assessment report will be resolved as the AGR Fuel Development and Qualification Program proceeds to completion. Other items, including those related to the need for initial core fuel proof testing, remain to be addressed by the applicant during the COLA or DC application phase of NGNP.

4.1.2 Licensing Basis Event Selection

The 2008 Report to Congress recommended that the NGNP licensing strategy use a RIPB technical approach that adapts existing LWR technical licensing requirements to create HTGR design-compatible licensing requirements. This approach makes use of deterministic judgment and analysis complemented by increased reliance of design-specific PRA to establish a licensing basis and requirements commensurate with the quality and completeness of the PRA that accompanies the application. This adaptation strategy, as opposed to creating a completely new and separate licensing framework for HTGRs, is a foundational presumption in the overall licensing framework advanced by NGNP.

The NRC Commission has recently placed increased emphasis on the use of probabilistic risk information for reactor licensing; further details are contained in Issue 4 of SECY-03-0047, March 28, 2003, and the SECY-03-0047 SRM guidance of June 26, 2003.

Using this guidance, the following RIPB elements have been integrated into the NGNP licensing approach:

- Identification of top level regulatory criteria (drawn from existing regulations) that are generic, quantitative, and direct measures of risk/consequence to the public
- Deterministic selection of LBEs based on engineering judgment and previous experience with modular HTGR studies
- Use of probabilistic methods to select LBEs for the modular HTGR design and thereby risk-inform the selection provided there is sufficient understanding of plant and fuel performance and if deterministic engineering judgment is used to bound uncertainties
- Use of a probabilistic approach to inform selection of safety classification of SSCs
- Replacement of the traditional single-failure criterion with a probabilistic criterion when developing event sequences.

On July 6, 2012, NGNP submitted a letter to NRC clarifying specific topics for which NRC staff positions were sought. Position Request 1.c of that letter requested evaluations that establish a staff position to support a final determination regarding how licensing basis events are to be considered for the purpose of plant siting and functional containment design decisions. This position would take into consideration previous staff positions in SECY-95-0299[51] that seek to improve fuel performance and is justification for revising siting source terms and containment design requirements. In particular, NGNP requested that this staff position provide for adaptation of the guidance that is being generally applied to LWRs for compliance with 10 CFR 100.21.[52] For LWRs, this guidance has typically included the assumption of a substantial meltdown of the core with subsequent release of appreciable quantities of fission products; See Appendix B of this report for further information.

Licensing Basis Event Selection Process White Paper

Purpose

Using performance-based systems that are informed by estimated actual risk, the Licensing Basis Event Selection White Paper[53] outlined a systematic methodology for use when selecting and classifying LBEs for the NGNP design. This methodology integrated deterministic safety principles and PRA insights as critical inputs to LBE selection. It also addressed scenarios where mechanistic source terms can be applied to assess impact on offsite dose criteria and presented a methodology for determining the spectrum of LBEs to be considered in an HTGR. A means for selecting and classifying LBEs was also identified, as were supplemental issues for regulatory discussion concerning the spectrum of events to be considered.

Outcome Objectives

The white paper requested NRC staff agreement concerning adequacy of the proposed LBE selection approach for HTGRs and solicited additional feedback on details that might affect preparing the NGNP COLA. Objective discussions centered around a process for selecting LBEs, a spectrum of normal operation to rare off-normal events, the frequency of LBEs expressed in units of events per plant-year, established acceptable limits on event sequence consequences, and the kinds of events, failures, and natural phenomena to be evaluated during the analysis. The HTGR design basis accident philosophy was also examined as were uncertainty distributions associated with LBEs.

Requested NRC Staff Positions

Subsequent to the white paper submission, NGNP submitted a letter[31] to NRC further refining LBE subject matter objectives. This correspondence requested NRC staff to endorse the following:

- Agree with the placement of top-level regulatory criteria (TLRC) on a frequency-consequence (F-C) curve. The TLRC establish the quantitative, direct measures of public safety acceptance criteria, which are to be met. These criteria would provide the technical basis for ensuring that the design meets applicable top-level public health and safety regulatory criteria. The proposed NGNP F-C curve is illustrated in Figure 2
- Agree with the established frequency ranges based on mean event sequence frequency for the LBE event categories
- Endorse the "per plant-year" method of addressing risk at multi-reactor module plant sites
- Agree on key terminology and naming conventions for event categories
- Agree on the frequency cutoffs for design basis event (DBE) and beyond design basis event (BDBE) regions
- Endorse the overall process for performing assessments against TLRC, including issues with uncertainties and the PRA, the calculational methodologies to be employed (conservative versus best estimate), and the adequate incorporation of deterministic elements.

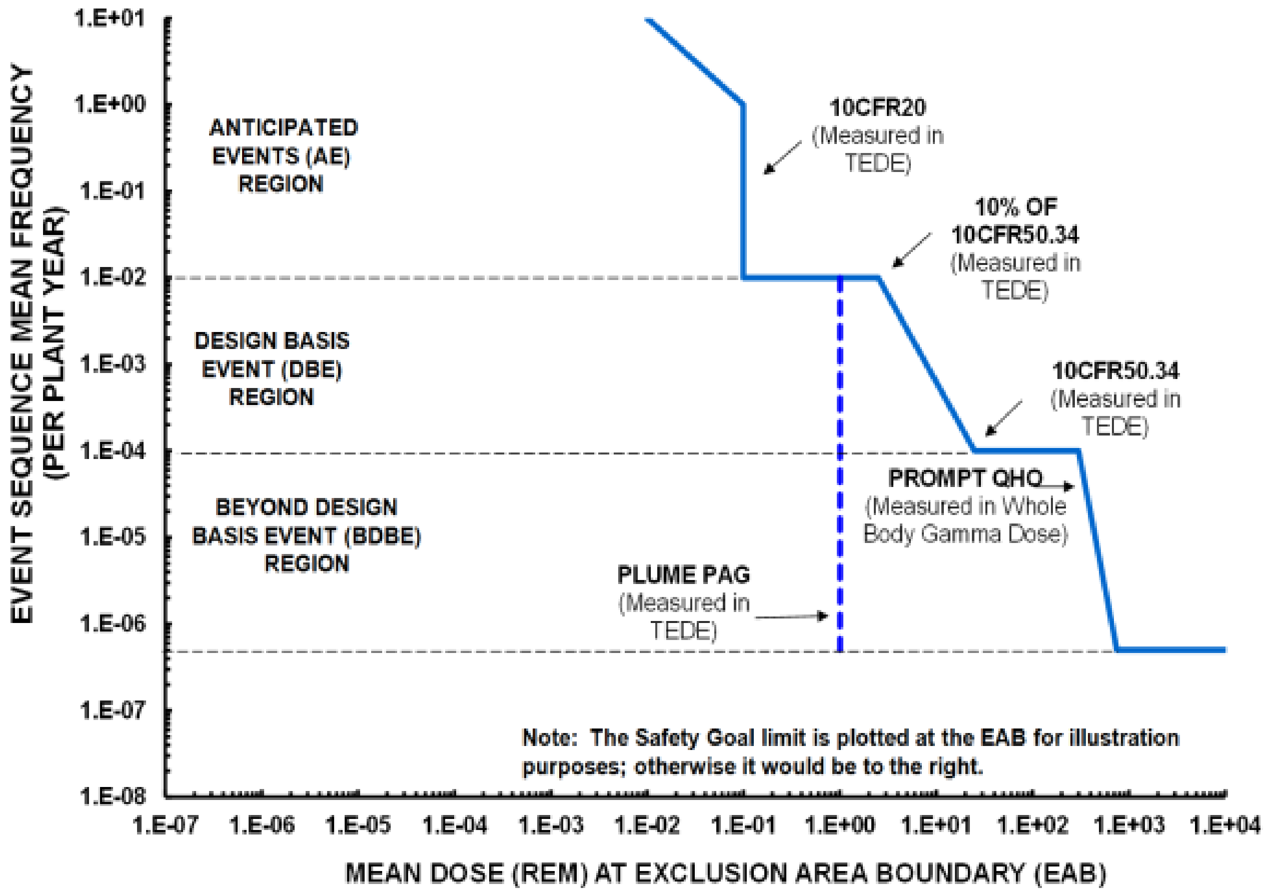

Figure 2. NGNP top-level regulatory criteria on a frequency-consequence curve for licensing basis event selection.

The acceptable limits on event sequence consequences (for the associated LBE categories) were proposed as:

- Anticipated Events (AEs) – 10 CFR Part 20: 100 mrem total effective dose equivalent (TEDE) mechanistically modeled and realistically calculated at the EAB, on a cumulative annual basis[54]
- Design Basis Events (DBEs) – 10 CFR §50.34/10 CFR §52.79: 25 rem TEDE mechanistically modeled and conservatively calculated at the EAB, on a per-event basis[7,27]
- Beyond Design Basis Events (BDBEs) – NRC Safety Goal quantitative health objectives (QHOs) mechanistically modeled and realistically calculated, on a cumulative basis with the AEs and DBEs, at 1 mi (1.6 km) and 10 mi (16 km) from the plant.

Frequency ranges based on mean event sequence frequency would be established for the LBE event categories. Uncertainty distributions are to be evaluated for the mean event sequence frequency and the mean consequence for each LBE. The mean frequency is to be used to determine whether the event sequence family is an AE, DBE, or BDBE. If the upper or lower bound on the LBE frequency straddles two or more regions, the LBE is compared against the consequence criteria for each region. The mean, lower (5%) bound, and upper (95%) bound consequences are to be explicitly compared to the consequence criteria in all applicable LBE regions. The NGNP approach of using the mean event sequence frequency plus uncertainty distributions is consistent with the approach presented in ANS 53.1.[13]

Interactions and Outcomes

The Licensing Basis Event Selection white paper was submitted to the NRC on September 16, 2010. An overview of the paper was presented to the NRC staff in a public meeting at NRC Headquarters on November 2, 2010.

Based on staff review of the white paper, NRC requested additional information and clarification in NRC Letter No. 005.[55] This document contained LBE-related RAIs (the original enclosure contained 40 LBE-related RAIs, but five were later redacted). NGNP responded to these RAIs in a letter dated October 14, 2011.[56]

A public meeting was held at NRC Headquarters on April 16, 2012 to further staff understanding of NGNP positions presented relative to LBE selection. This meeting also expanded upon the basis for developing the HTGR F-C curve and related LBE categories. Handouts from this meeting can be found in ADAMS (ML12104A150).

A follow-on public meeting was held with the staff on May 16, 2012, to further discuss issues associated with using event sequence frequency, per plant-year evaluations, and treatment of anticipated operational events (AOOs) now called AEs; handouts from this meeting can be found in ADAMS (ML12136A102).

A public meeting was added on July 10, 2012, to provide NGNP responses to a series of actions undertaken as a result of the May 16, 2012, meeting. These actions included a requested comparison of the F-C curve to other suggested curves (including the one found in NUREG-1860). The MHTGR LBEs were also compared (on an F-C curve) to design basis accidents (DBAs) and elements related to how uncertainties would be addressed were discussed, as was how DBAs could extend into the BDBE region. The handouts from this meeting can be found in ADAMS (ML12223A094).

A further series of public meetings were held with the staff to discuss a variety of follow-up items that included issues related to LBE. These meetings were held on August 22, 2012, (ML12255A134), September 19, 2012,[57] (Handouts: ML12262A090), and November 14, 2012.[58]

NRC staff review outputs concerning the proposed event selection process focuses on two documents: (1) An initial draft staff assessment report issued in March 2013, and (2) a later "non-draft" assessment report issued in July 2014. Because these documents discussed the LBE selection process quite differently, both documents are relevant to understanding the staff level of acceptance of the NGNP proposal. This feedback is summarized below.

1. <u>*Office of New Reactors – Summary Feedback on Four Key Licensing Issues – Draft Enclosure 1 – March 2013 (ML13002A157)*</u>

   This document discussed an initial NRC staff assessment of the proposed NGNP LBE selection approach. In general, it concluded that the majority of the NGNP proposal appeared reasonable.

2. <u>*Next Generation Nuclear Plant – Assessment of Key Licensing Issues – July 2014 (Cover Letter – ML1417A734 and Enclosure 1 – ML1417A774)*</u>

   Following issuance of the draft NRC staff position and the May 2013 ACRS recommendations concerning LBE selection[32], NRC staff issued a follow-on report. This document updated the earlier draft assessment document but discussed the proposed process in different terms.

   The "Summary and Conclusions" portion of this assessment stated that:

   "*This summary feedback document, and the more detailed feedback in the NRC staff's updated FQ- MST assessment report, conclude that the proposed risk-informed framework and performance-based criteria for licensing the NGNP prototype present a generally reasonable* *approach for implementing the framework outlined in the joint NGNP Licensing Strategy Report of 2008."*

However, both the assessment report cover letter and portions of the body of Enclosure 1 indicated that NRC has decided to withhold any further feedback regarding the proposed risk-informed performance-based approach at that time. Reference to the reasons for the deferral included ongoing NRC staff work related to:

- SECY-13-0132, "U.S. Nuclear Regulatory Commission Staff Recommendation for Disposition of Recommendation 1 of the Near Term Task Force Report" and related Commission SRM associated with addressing the objectives of Improvement Activities 1 and 2, as appropriate, in the context of the Commission's direction on a long-term Risk Management Regulatory Framework (RMRF)
- The establishment of a risk management regulatory approach associated with the approach discussed in NUREG-2150, "A Risk Management Regulatory Framework."

3. *<u>NRC Non-Concurrence Process for Next Generation Nuclear Plant – Assessment of Key Licensing Issues – NCP-2013-015 (initiated December 12, 2013) and NCP-2014-007 (initiated May 23, 2014)</u>*

Some NRC staff members directly involved with multi-year interactions on NGNP event selection topics did not concur with the removal of draft guidance and assessment feedback from the July 2014 report [see ADAMS for NRC Non Concurrence Process documents NCP-2013-015 (ML14126A242) and NCP-2014-007 (ML14154A080)]. This guidance and assessment feedback information was removed based on a desire to avoid issuing preliminary guidance in areas that "relate to pending NRC activities related to Near Term Task Force (NTTF) Recommendation 1 and the RMRF outlined in NUREG-2150." Authors of NCP-2014-007 disagreed with this concern and noted the original July 2014 report language "already included adequate caveats that referred in general to potential needs for Commission policy guidance and specifically to potential linkages with conceptually similar issues to be considered in the contexts of NTTF Recommendation 1 and NUREG-2150." The basis for the NCP authors' concerns (summarized from NCP-2014-007) included:

- NTTF Recommendation 1 focuses on large LWRs; any RMRF to implement the objectives of NTTF Recommendation 1 will "appropriately incorporate LWR safety paradigms that do not apply to modular HTGRs." HTGR designs can preclude extensive core damage of the kind that occurs rapidly in all LWR accidents that uncover the core. In addition, HTGR designs will attempt to demonstrate that modular HTGR severe accident behavior "inherently lacks anything resembling the cascading 'cliff edge' effects of core damage, vessel failure, and containment breach that appear in LWR severe accidents." The NCP authors also noted that developers of modular HTGRs "have been proactive in proposing sets of licensing basis events and requirements that extend well beyond the design basis. Therefore, any new LWR regulatory considerations of design-basis extension requirements stemming from the NTTF Recommendation 1 objectives are likely to be generally consistent with, and amply addressed by, the approaches long proposed by modular HTGR developers."
- An appendix in NUREG-2150 includes a copy of the frequency-consequence (F-C) curve proposed for NGNP. The NCP authors noted, "It can thus be expected that any future frameworks for advanced reactors that build upon concepts outlined in NUREG-2150 and NUREG-1860 will remain largely consistent with most of our feedback on the conceptually similar technology-specific licensing framework proposed for NGNP." Authors also noted that the proposed NGNP F-C curve aligns favorably with the ACRS view that the NUREG-1860 F-C curve is overly restrictive at the higher event frequency ranges. Based on these

points, the NCP authors did not agree that any pending or new risk management regulatory framework efforts would alter the staff's assessment feedback on the LBE selection, SSC safety classification, and DID approaches proposed for NGNP.

Non Concurrence Process document NCP-2013-015 focused on the exclusion of three paragraphs that NCP authors desired to insert. These paragraphs clarified the initial NRC staff assessment of the DOE/INL proposal to use an event sequence frequency selection of 1×10^{-4} per-plant year for the lower threshold of events included in the design basis. The basis for this lower threshold value was contained in the NGNP LBE Selection White Paper, which referenced the Commission's SRM to SECY-90-016 as supporting the proposed frequency cutoff.

In their assessment not included in the July 2014 report, NCP authors took issue with this basis by noting that the white paper included "some less relevant and potentially confusing assertions in reference to the core damage frequency (CDF) goal" that was established by the Commission in the SRM to SECY-90-016. As a point of clarification, the NCP authors stated, "a CDF below 10-4 per reactor-year can only be achieved if each accident that contributes to the total CDF has a frequency well below 10-4 per reactor-year." In conclusion, the NCP authors stated, "We have come to the shared view that neither SRM-SECY-90-16 nor SRM-SECY-04-0037 provides guidance that is directly relevant to modular HTGRs. This view is based on our current understanding of the defining safety features of the modular HTGR design concept… Even in extreme bounding accidents far beyond the design basis, future applicants intend to show that any resulting core degradation in modular HTGRs would be very limited and incremental and evolve very slowly in relation to the extensive and rapid core damage that can occur in today's LWRs in accidents only moderately beyond the design basis."

Although NGNP prelicensing activities did advance NRC staff knowledge and acceptance of the proposed approaches to event selection, that progress was not reflected in the July 2014 staff assessment report. This leaves some critical issues related to licensing basis event selection largely unresolved and a source of ongoing regulatory uncertainty to the commercial advanced reactor community. It is recommended that future modular HTGR licensing efforts utilize both NRC staff assessment reports as a starting point for continuing dialogue with NRC on this topic.

4.1.3 Source Terms

Radiological source terms are required when assessing dose to workers and the public, when comparing releases against select regulatory criteria, and when assessing equipment reliability and capability. A plausible radiological source term is essential to licensing a nuclear facility.

Up to now, much of the bounding source terms has been defined in consideration of a footnote appearing in 10CFR 52.79(a). This footnote in current nuclear plant siting regulation is predicated on deterministic evaluations of a large fission product release from a substantially melted LWR core to an intact reactor containment building. Because this accident assumption (i.e., substantial core melt) is not plausible with a modular HTGR, the applicability of this footnote is called into question. Clarification of footnote applicability and other issues related to establishing HTGR mechanistic source terms were the focus of NGNP interactions with NRC staff.

Mechanistic Source Terms White Paper

Purpose

The Mechanistic Source Terms White Paper[37] summarizes the event-specific mechanistic approach taken by NGNP in developing radiological source terms for modular HTGR LBEs. Source terms developed with this approach are coupled with radionuclide inventories elsewhere in the facility and used for multiple purposes that include equipment environmental qualification, control room habitability analyses, and assessment of severe accident risks in environmental impact evaluations. A mechanistic approach to source term development is necessary to establish both the technical basis for potential radiological emissions and provide credit for the radionuclide retention capabilities of the multiple transport barriers that are present consistent with HTGR safety design. The white paper also discussed major VHTR technology development programs that are validating design and predictive methods for HTGR mechanistic source terms.

Outcome Objectives

NGNP sought NRC feedback and input on the adequacy of a proposed event-specific mechanistic source terms approach suitable for modular HTGRs. The following topics were identified for discussion:

- That the NGNP definition of event-specific mechanistic source terms for the HTGR is acceptable
- That the approach to calculating event-specific mechanistic source terms for HTGR technology is acceptable (subject to validation of the design methods and supporting data that form the bases of the calculations)
- That the approach of planned fission product transport tests under the NGNP/AGR Fuel Development and Qualification Program, as supplemented by the existing irradiation and post-irradiation heating databases to validate these fission product transport analytical tools, is acceptable.

Requested NRC Staff Positions

On July 6, 2012, NGNP submitted a letter to NRC clarifying specific topics for which NRC staff positions were sought.[31] Relative to mechanistic source terms development, NGNP specifically requested the following (position requests 3a, 3b, and 3c):

- Endorse the proposed NGNP mechanistic source terms definition by the quantities of radionuclides released from the reactor building to the environment during the spectrum of licensing basis events, including timing, physical and chemical forms, and thermal energy of the release
- Agree that NGNP source terms are event specific and determined mechanistically using models of radionuclide generation and transport that account for fuel and reactor design characteristics, passive features, and the radionuclide release barriers
- Agree that NGNP has adequately identified key HTGR fission product transport phenomena and established acceptable plans for evaluating and characterizing those phenomena and associated uncertainties.

Further information on the subject is provided in Appendix B of this report.

Interactions and Outcomes

The Mechanistic Source Terms White Paper was submitted to NRC on July 21, 2010.[59] An overview of the document was provided to NRC staff in a public meeting on September 2, 2010.[60]

NRC staff reviewed the Mechanistic Source Terms and the Fuel Qualification White Papers as a single package and requested additional information and clarification on June 7, 2011.[39] That document contained 118 RAIs, most of which were related to mechanistic source terms. NGNP responded to the RAIs in a letter dated August 10, 2011.[40]

A public meeting was held with NRC staff on October 19, 2011, to discuss NGNP responses to the mechanistic source terms RAIs. Handouts for this meeting are available in ADAMS (ML113000320).[43]

On February 15, 2012, NRC transmitted a staff working group draft assessment report, "Assessment of White Paper Submittals on Fuel Qualification and Mechanistic Source Terms."[44] Outstanding issues related to this initial assessment were tabulated in a spreadsheet used to track progress on discussion and resolution of follow-up items. Public meetings were also held on April 17, 2012[45] and July 24, 2012[46] with NRC staff to further resolve outstanding issues.

Other public meetings also addressed topics related to the NGNP mechanistic source terms. On July 11, 2012, a meeting was held to discuss the functional containment performance for the modular HTGR.[61] A meeting was held on September 20, 2012, at which NGNP's approach to developing siting source terms was discussed.[62,63] This meeting addressed applicability of the 10 CFR 52.79(a) footnote on accident sequences for site suitability assessment. In this particular matter, NGNP took the position that a portion of the footnote constituted guidance rather than a specific regulatory requirement. A follow-up public teleconference dealing with siting source terms and bounding event sequences involving graphite oxidation was held on November 14, 2012.[58]

NGNP briefed the ACRS Future Plant Designs Subcommittee about NGNP approaches on January 17, 2013,[47] and addressed mechanistic source terms. The NRC staff issued an updated draft position on the proposed NGNP approach on March 11, 2013 (ML13002A168). NRC staff then briefed the ACRS subcommittee on their position on April 9, 2013. After that, NGNP and NRC jointly briefed the ACRS Full Committee on May 9, 2013. The ACRS issued a letter summarizing committee findings relative to mechanistic source terms (and other NGNP prelicensing review topics) on May 15, 2013 (see Section 4.2 for more information).

NRC staff determinations regarding the NGNP Mechanistic Source Terms White Paper are documented in ML14174A845, "Assessment of White Paper Submittals on Fuel Qualification and Mechanistic Source Terms (Revision 1)" Enclosure 2.[48] In it, the NRC staff stated that the proposed definition of the NGNP mechanistic source term is reasonable. It also indicated that the event-specific, mechanistic approach is reasonable but remained subject to resolution of several follow up items. Most of these items are expected to be resolved as the AGR Program and NGNP design efforts proceed to completion. While the NRC staff identified no specific gaps in AGR Program fission product transport work, certain questions do remain regarding the appropriateness of using effective diffusion coefficients to characterize complex radionuclide transport phenomena in graphite and whether radionuclide diffusion rates may be accelerated in a neutron flux field.

NRC staff also indicated agreement with the proposed NGNP interpretation for applying the 10 CFR 52.79(a) footnote on modular HTGR siting source terms and engineered safety design features. It is reasonable to assume that fission product releases for site evaluation can be based on plausible postulated accidents, supplemented by insights derived from a spectrum of limiting, mechanistically evaluated events and supplemented by credible bounding event sequences.

It is anticipated that many of the mechanistic source term follow-up questions identified as outstanding by NRC staff will be resolved when the AGR Fuel Development and Qualification Program is completed. Questions not addressed by that program include resolution of fuel performance and source term uncertainties. These issues may require prototype testing and implementing special programs for operational surveillance, monitoring, testing, and inspection at the NGNP plant. These issues become the responsibility of the applicant to resolve during the COLA or DC application development phase.

4.1.4 Emergency Planning

Since 1978, the established basis for current plume exposure pathway emergency planning zone (EPZ) (of about 10 mi) and ingestion exposure pathway EPZ (of about 50 mi) has been applied to large LWRs. Since then, the staff has indicated willingness to consider alternative emergency planning (EP) and EPZ distance requirements for small modular reactor facilities; this intent is documented in SECY-11-0152, "Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors."[64] This SECY also outlines an approach that can be used when determining appropriate EPZ size (on a case-by-case basis) for modular HTGRs.

The SECY-11-0152 discussions generally aligned with the NGNP EP proposal contained in a white paper submittal to the NRC. To further a technology-neutral, dose-based EP framework that accounts for modular HTGRs collocated with industrial processes, NGNP initiated discussions with NRC staff in order to:

- Propose a new policy or revised regulation on scaling EPZ size commensurate with an accident source term, fission product release, and associated dose characteristics
- Establish guidance concerning how the EP requirements of 10 CFR 50 specific to LWRs can be applied in a graded manner that allows NGNP to demonstrate compliance with PAG values in accordance with its stated current design goals
- Propose guidance regarding how design modularity and collocation near industrial sites can be considered in EP planning.

It is expected that NGNP will be collocated with another non-nuclear industrial facility. EP issues related to licensing advanced nuclear plants collocated with industrial facilities could be managed similar to those LWRs that are currently situated near industrial facilities.

Emergency Planning White Paper

Purpose

In 2009, NGNP staff performed a study on the regulatory history and criteria related to defining plume exposure and ingestion pathways as they connect to an EPZ footprint. Conclusions from that study indicated a pathway existed for satisfying NGNP emergency planning requirements while providing for a reduction of the plume exposure EPZ to the exclusion area boundary and a reduction of the ingestion pathway EPZ (i.e., for which action may be required to protect the food chain) to a size appropriate to HTGR accident source terms.

The purpose of, "Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR,"[65] was to describe an approach for sizing the NGNP EPZ and discuss the ramifications of EPZ size reduction with respect to plume exposure and ingestion pathways.

Outcome Objectives

This document solicited NRC review and concurrence on key information related to EPZ sizing at NGNP. Issues for discussion included:

- The design and operating characteristics of HTGR and the emergency planning requirements consistent with enhanced safety margins and reduced risk associated with reactor design and the NGNP DID methodology
- Confirmation that EPZ sizing could be determined, in part, by evaluating the offsite dose consequences of design basis events and design basis threats to determine distances at which the lower limit of the EPA PAG are met

- Concurrence that technical justification for EPZ size could be based on the absence of a significant radiological release during an accident, thereby allowing offsite emergency response to be accommodated (at least in part) through all-hazards plans that may already exist at a collocated industrial facility
- Compliance with the emergency planning requirements of 10 CFR 50 can be established and confirmed on a graded approach that allows site and offsite emergency plans to be developed commensurate with the HTGR design.

Requested NRC Staff Positions

Subsequent to white paper submission, NGNP submitted a letter[31] to NRC further refining emergency planning and EPZ sizing objectives. This correspondence requested NRC staff to:

- Propose a new policy or revised regulations for how the emergency planning zone sizing can be scaled to be commensurate with the accident source term, fission product release, and associated dose characteristics
- Propose guidance regarding how issues related to modularity of the designs and the co-location of multi-module plants near industrial facilities should be considered in EP planning.

Interactions and Outcomes

The white paper, "Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for a High Temperature Gas Reactor," INL/MIS-10-19799, was submitted to NRC on October 28, 2010. A public meeting was held with the NRC staff on January 26, 2010, to discuss the paper.[65]

In October 2011, NRC issued SECY-11-0152, "Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors."[64] This paper discussed the staff's intention to develop a technology-neutral, dose-based, consequence-oriented emergency preparedness framework for SMR sites that takes into account the various designs, modularity, and collocation, as well as the size of the EPZ. The SECY referenced and briefly discussed the NGNP white paper on emergency planning.

A second meeting with the NRC staff was held on November 14, 2012, to discuss, in part, the proposed NGNP emergency planning event selection process.[58] In the meeting, NRC staff voiced general agreement in principle regarding the use of dose to determine appropriate facility EPZ size. However, the staff also questioned the use of "mean" analysis values for evaluating design basis events when determining the distance at which the lower EPA PAG limits are understood as met for each event scenario.

As of July 2014, NRC staff has not provided NGNP formal regulatory feedback in response to specific emergency planning white paper objectives. However, NRC staff did indicate willingness to consider applicant requests to establish a technology-neutral, variable distance plume exposure EPZ (ML14174A774). In a briefing to the ACRS subcommittee held on April 9, 2013, the NRC staff commented that NGNP's proposed EP approach was generally reasonable and responsive to the Commission's Policy Statement on Advanced Reactors (see Section 6.1 for policy statement discussions). The staff also stated that it is open to considering alternative EP requirements and frameworks for advanced reactors and SMR facilities but does not plan (in the near term) to propose additional new EP policies or to revise the existing guidance for addressing EP requirements.

Consequently, the only available document that reflects NRC staff thinking regarding NGNP proposed emergency planning criteria is SECY-11-0152. This SECY, based in-part on proposals contained in the NGNP white paper, indicated a position that it is appropriate to consider applicant requests for establishing technology-neutral, variable distance, plume exposure EPZs for SMRs. The staff also indicated a plan to provide implementation details of the SMR emergency preparedness framework as it is developed and will likely issue policy statements in the form of NRC position papers.

4.2 Recommendations from the Advisory Committee on Reactor Safeguards

As already discussed, the ACRS Full Committee met on May 9, 2013 to review draft NRC staff assessments of key U.S. DOE/INL NGNP licensing issues. This particular meeting followed two earlier ACRS Future Plant Designs Subcommittee reviews; one covering key DOE/INL pre-licensing issue white papers (January 17, 2013) and the other covering preliminary NRC staff assessments of the white papers (April 9, 2013). All three ACRS meetings included interactive discussions with representatives of the NRC staff, DOE, and NGNP. The last meeting resulted in a letter from the ACRS that contained recommendations for subsequent consideration by the Commission.[32]

In summary, the ACRS Full Committee recommendations indicated that:

1. The staff assessment of the NGNP white papers on key technical issues is appropriate, given the unavailability of many plant-specific design details, such as the selected fuel form (pebble or prismatic) and a complete plant design. The final assessments should be published after the issues raised in Recommendations 2, 3, and 4 (below) are addressed
2. The staff assessment documents should be revised to provide clear links to the numerous requests for additional information (RAIs) and responses that were developed during their assessment because the white papers have not been revised to incorporate those agreements
3. The licensing basis event selection assessment should point out the need to clarify the definition of event sequences and event sequence families to ensure consistency in developing licensing basis events and design basis accidents, and
4. The staff's suggestion that the final selection of DBAs include postulated deterministic event sequences is inconsistent with the risk-informed framework proposed by the NGNP project and with other on-going NRC activities encouraged by the Commission. Although engineering judgment may be invoked to include postulated deterministic event sequences in the final selection of DBAs, if such sequences are not in the probabilistic risk assessment (PRA), the PRA is incomplete and should be revised to include them. They then can be fully evaluated and considered for inclusion as DBAs.

These recommendations were conveyed to NRC staff for consideration in developing a subsequent staff assessment. As summarized in the subsections above, follow-up assessment documents were released on July 17, 2014.[48]

4.3 Other Key Prelicensing Topics

4.3.1 Additional Risk-Informed Performance Based Licensing White Papers

The following subsections discuss other NGNP white papers and contribute to the definition of key aspects of the proposed RIPB approach. These summaries supplement the licensing basis event selection discussions provided in Section 4.1.

Defense in Depth Approach

Purpose

NGNP developed a white paper dedicated to applying the DID philosophy at NGNP.[66] The white paper defined DID in the context of an HTGR and outlined an approach which assured DID principles are systematically applied to NGNP. The paper identified existing regulations, guidance and precedents relative to enabling the approach and described a DID framework formed upon programmatic and risk-informed evaluation elements. The document also posed specific questions about DID to the NRC.

Outcome Objectives

Using the DID white paper, NGNP held discussions with the NRC staff to:

- Confirm that the summary of regulatory requirements, guidance, and precedents that apply to DID in general could be applied to an advanced HTGR design
- Propose a definition of DID appropriate to non-LWR technologies and assure this definition compares favorably with the definitions typically used now by NRC
- Describe the methodology for achieving DID in plant design and operation
- Identify how the proposed DID approach addresses the role of special compensatory measures for unique first-of-a-kind issues associated with the NGNP design
- Recognize the methods for regulatory acceptance of the proposed DID approach
- Show how the NGNP DID approach aligns with standing NRC expectations for greater use of risk-informed licensing practices
- Identify policy, technical issues, and outcome objectives for additional examination and discussion with the NRC.

Interactions and Outcomes

NGNP submitted INL/EXT-09-17139, "Next Generation Nuclear Plant Defense-in-Depth Approach," to NRC on March 9, 2009. An overview of the NGNP DID approach white paper was provided to NRC staff in a public meeting on March 8, 2010; the discussion was documented in a meeting summary dated September 29, 2010.[67]

On July 26, 2010, the NRC transmitted six RAI's to NGNP regarding the proposed DID approach.[68] NRC staff noted in this letter that additional DID RAIs may be forthcoming after reviews are completed on other white papers that contribute to the overall NGNP RIPB framework. NGNP Regulatory Affairs provided written response to the six NRC inquiries.[69]

The NRC staff reviewed the proposed DID approach as part of a broad examination of the NGNP RIPB approach. Based on their review of other related white papers, the staff requested additional information and clarifications in NRC Letter No. 005.[55] The NRC issued 34 RAIs related to DID (the enclosure contained 36 DID RAIs, but two were later redacted) that included questions regarding how deterministic engineering judgments were to be used. NGNP responded to these RAIs in a letter dated October 14, 2011.[56]

NRC staff did not make a formal determination on the adequacy and sufficiency of the proposed DID approach. Further decisions on the topic were to be deferred until the Commission provides additional policy direction. However, the staff informally commented during interactions that the plant capability portion of the proposed defense in depth framework appeared to be a logical approach.

Approach for Incorporating Probabilistic Risk Assessment

Purpose

The NGNP Probabilistic Risk Assessment (PRA) White Paper[70] outlined an approach to develop a PRA for NGNP and subsequent modular HTGRs. The document was written to confirm the acceptability of a refined PRA process that is supportive of NGNP licensing. It included evaluation of design options that incorporate risk insights and input to the selection of LBEs and safety classification of SSCs. The PRA approach also applied to evaluation of DID measures.

The paper also identified policy and guidance statements that underlie the overall NGNP PRA formulation. It noted key regulatory issues concerning how white paper objectives can be factored into the framework. To this, the NGNP PRA is introduced early in the design stage and is upgraded as design and licensing details are defined. Doing this provides applicants opportunities to optimize the design relative to safety and licensing and define prerequisite SSC capabilities and reliability using PRA methods.

Outcome Objectives

NGNP sought concurrence and comment from NRC staff on the adequacy of the proposed PRA approach. Feedback was solicited on issues that affect COLA development and scheduling. Specific objectives included:

- Confirming that the approaches to initiating event selection, event sequence development, end state definition and definition of risk metrics are appropriate
- The treatment of inherent characteristics and passive SSCs as outlined in the paper is reasonable and consistent with current state-of-the-art PRAs
- Using deterministic engineering analyses to provide a technical basis for predicting plant response to initiating events and event sequences, success criteria, and mechanistic source terms yields an appropriate blend of deterministic and probabilistic inputs. Furthermore, the use of applicable data from LWRs, use of expert opinion, and treatment of uncertainty, is reasonable to the proposed approach
- Confirming that the process for representing uncertainties and the PRA quantification of mechanistic source terms (as outlined in the NGNP white paper on Mechanistic Source Terms) is reasonable and acceptable
- The PRA treatment of single and multiple reactor accidents is sufficient and that available guides and standards for PRA quality and independent peer review can be used
- The PRA approach for treating uncertainty is adequate and can be employed for risk-informed evaluations of DID for design, construction, and operation.

Interactions and Outcomes

The NRC staff did not provide written feedback in response to the objectives of the NGNP PRA white paper. However, during the course of interactions, the staff informally commented that the current LWR fleet did not use PRA event sequences to establish the licensing basis. Therefore, requirements and guidance for technical adequacy are necessary for PRAs used to select events included in the licensing basis. These requirements will be different and likely more demanding when compared to that used by the current fleet of LWRs. It was also noted that the proposed PRA methodology for identifying potential initiating events was similar to that used in LWR PRAs and includes challenges posed during all operating and shutdown modes of operation applicable to the NGNP. The staff indicated that this is reasonable and consistent with approaches used by new LWR designs. However, the PRA white paper did not provided a clear definition of the risk metrics to be used for the NGNP plant. In this regard, the staff observed that risk metrics should include event sequence frequencies associated with LBEs that would result in bounding source terms.

Many follow-up items related to the objectives of this white paper remain unresolved at the conclusion of NGNP prelicensing discussions. The applicant must address remaining issues during the COLA or design certification phase of NGNP.

Structures, Systems, and Components Safety Classification

Purpose

Another NGNP white paper written to deal with structures, systems, and components safety classification[71] proposed a regulatory policy and guidance structure necessary to support a RIPB approach in SSC safety classification. The NGNP safety classification scheme denoted SSCs as either safety-related, non-safety-related with special treatment (NSRST), or non-safety- related. The safety SSC classification is applied after LBEs and necessary related safety functions are identified. Plant SSCs that are available to satisfy the required safety functions are evaluated for the safety-significant role they play in preventing or mitigating radiological consequences of the adverse event and in consideration of facility DID attributes.

The SSC safety classification white paper, along with the white papers on defense-in-depth and licensing basis event selection, combine to form an integrated foundation for an overall risk-informed, performance-based approach.

Outcome Objectives

This white paper informed the NRC about the proposed SSC classification approach and solicited feedback and agreement on a proposed scheme that covers the entire nuclear plant life cycle. Specific objectives included:

- Confirming the NGNP risk-informed safety classification and special treatment approach to blending the strengths of probabilistic and deterministic methods is acceptable
- Ensuring the NGNP risk-informed safety classification categories and the basis for SSC classification within each category is acceptable
- The special treatment of the safety-related category of classification is commensurate with ensuring the SSCs ability to perform their respective safety function for design basis events and high consequence beyond design basis events
- The special treatment for the NSRST category is commensurate with ensuring the SSCs ability to perform their safety function of providing significant defense-in-depth.

Requested NRC Staff Positions

Subsequent to white paper submission to the NRC, NGNP submitted a letter[31] to NRC further refine LBE subject matter objectives. This correspondence requested the NRC to endorse the proposed process and categorizations for SSC classification.

Interactions and Outcomes

NGNP transmitted the NGNP SSC safety classification white paper to the NRC for review on September 21, 2010.[72] NGNP provided a presentation of white paper contents to NRC staff in a public meeting conducted on November 2, 2010 (ML103070071).

Based on NRC staff reviews of the SSC white paper and the public meeting, the staff issued 27 RAIs in RAI Letter No. 005, dated August 3, 2011.[55] NGNP provided a response to these RAIs on October 14, 2011.[56]

Several additional public meetings that included NGNP SSC discussions were held with the NRC staff. These included meetings held at NRC Headquarters on April 16, 2012 (slides ML12104A150),[73] May 16, 2012 (slides ML12136A102),[74] July 10, 2012 (slides ML1223A147),[75] August 22, 2012,[76] and follow-up discussions on September 6 and 19, 2012.[77]

The topic of SSC safety classification was also discussed in the ACRS subcommittee meeting held on April 9, 2013.

Initial interactions and draft NRC assessment findings (see ML13002A157) indicated NRC staff found:

- NGNP's approach to risk-informed safety classification of SSCs to be generally reasonable. The approach blends strengths of probabilistic and deterministic methods in accordance with NRC's policy statement on PRA
- The proposed risk-informed safety classification categories and criteria for SSC classification within each category are generally reasonable
- For modular HTGRs, NGNP had not yet developed design limits analogous to the specified acceptable fuel design limits (SAFDL) used in LWRs. The staff believed events should be established analogous to the SAFDL-related AOOs for LWRs
- Any operational events or AEs that have a potential to challenge design limits for modular HTGRs should be evaluated conservatively relative to those limits and credit only safety-related SCCs for mitigation. Then, AE dose consequences can be compared to the 10 CFR 20 criteria using a realistic best-estimate evaluation that includes mean value from a mechanistic source term uncertainty analysis
- Special treatments for safety-related and NSRST categories of SSC classification should be commensurate with ensuring that SSCs can perform required safety functions for LBEs and provide for DID.

Although the staff initially indicated support for NGNP's use of a risk-informed approach for classifying SSCs, the July 17, 2014 NRC staff position document did not contain discussions that validated earlier statements regarding conservative treatment of AEs that challenge design limits with only safety-related SSCs credited for mitigation. Differences between the risk-informed approach in determining and assessing AEs, as compared to the traditional LWR approach for AOOs, will require additional discussion between applicants and NRC staff. Please note that more detailed design information than is currently available may be necessary to enable NRC staff acceptance of a proposed risk-informed approach to the classification and treatment of SSCs.

4.3.2 Other Licensing White Papers

License Structure for Multi-Module Facilities

Purpose

The "License Structure for Multi-Module Facilities White Paper"[78] described the NGNP proposal regarding multi-module HTGR plant licensing with a single NRC review, hearing, and safety evaluation report. It also described the structure and duration of license for each module.

Outcome Objectives

This paper sought to inform the NRC and secure feedback on a proposed method for multi-module reactor licensing. Specifically, NRC was requested to concur with the following or provide acceptable alternative statements:

- That a single application for a Part 52 COLA can include multiple, essentially identical reactor modules, regardless of the size of the reactors
- That a single application with multiple (e.g., upwards of ten), essentially identical reactor modules can undergo a single NRC review, safety evaluation report, and NRC hearing
- The license duration for each module within a single license authorization is a period not to exceed 40-years from the date the Commission finds that the acceptance criteria in the license are met in accordance with §52.103(g) for that module

- In the case of issuing a separate license for each module at a site containing multiple, essentially identical modules, no Commission policy issue decision is necessary.

Interactions and Outcomes

In response to the NGNP white paper and other related industry initiatives regarding small modular reactors, the NRC issued SECY-11-0079, "License Structure for Multi-Module Facilities Related to Small Modular Nuclear Power Reactors,"[79] dated June 12, 2011. In the SECY, the staff endorsed the NGNP positions that:

- A single Part 52 COLA can include multiple, essentially identical reactor modules, regardless of the size of the reactors
- That a single application with multiple, essentially identical reactor modules can undergo a single NRC review, safety evaluation report, and NRC hearing
- That the license duration for each module within a single license authorization is a period not to exceed 40-years from the date the NRC finds that the acceptance criteria in the license are met in accordance with §52.103(g) for that module.

The staff indicated plans to engage a broad range of stakeholders to discuss alternatives and, absent compelling arguments for an alternative approach, further develop aspects of the positions contained in the NGNP white paper and submit a recommendation to the Commission for consideration and approval.

Nuclear-Industrial Facility and Design Certification Boundaries

Purpose

The "NGNP Nuclear-Industrial Facility and Design Certification Boundaries White Paper"[80] proposed to establish agreement with the NRC staff regarding the boundary between a nuclear facility under NRC regulatory jurisdiction (i.e., within the scope of the DC and COLA) and the interface to energy end use facility(s) that fall outside the scope of nominal NRC authority (i.e., the industrial facility). A clear description that defined plant scope addressed in the NGNP DC was also requested.

Outcome Objectives

White paper objectives included informing and soliciting NRC staff concurrence regarding the following:

- Define the boundary between the HTGR nuclear facility and the industrial facility with respect to regulatory jurisdiction
- Describe a typical nuclear facility design requirement and interface requirement necessary to define and ensure safe operations for an interconnected industrial facility
- Describe a minimum set of HTGR nuclear facility system and interface requirements addressed within the scope of the certified portion of a 10 CFR Part 52 DC and those appropriately described in a site-specific Part 52 COLA.

Interactions and Outcomes

Due to a lack of staff resources and a determination that the topic was of relatively low priority, the NRC did not review this white paper.

Modular HTGR Safety Basis

The "Modular HTGR Safety Basis and Approach" information paper[26] provided a summary level overview and descriptions of modular HTGR history, public safety objectives, inherent and passive safety features, radionuclide release barriers, functional safety approach, and the RIPB safety approach. This paper was submitted to NRC staff as a technical reference. Although the information it contained supported discussions of other NGNP white papers, the document was not submitted to the NRC for formal review and feedback.

Purpose

This paper offers NRC staff and other stakeholders a basic description of the safety concepts underlying the HTGR design. It also examines how the technological approach meets public safety requirements and how it differs from traditional LWRs.

Outcome Objectives

NGNP did not request NRC action or feedback on this white paper. Other NGNP white papers were written to address priority regulatory issues in HTGR licensing.

Interactions and Outcomes

No NRC assessment feedback was requested or provided. The paper continues to be available to the public as a key a reference for the HTGR technology employed by NGNP.

4.3.3 Research-Related White Papers

High Temperature Materials White Paper

Purpose

The NGNP High Temperature Materials white paper[81] reviewed policies, regulations, and guidance associated with use acceptance of materials in HTGR applications. NGNP developed a process for high-temperature component material selection and evaluation that leads to recommendations for qualification and acceptance. Principal materials proposed for NGNP primary systems were identified along with approaches for regulatory compliance. In cases where established qualification and acceptance was determined to be sufficient, regulatory issues were identified and a basis for resolution proposed. Metallic and nonmetallic materials for high-temperature NGNP service were identified and assessed in terms of supporting codes and standards and the existing basis for design and qualification. The processes for establishing expected material performance requirements under operating and accident conditions was also described.

Materials addressed in the white paper include high-temperature metals, graphite, carbon composites, and ceramic insulation. Final component specification and material selection has yet to be performed for NGNP so candidate materials in specific applications were discussed in the white paper to identify potential qualification and acceptance gaps.

Outcome Objective

The High Temperature Materials White Paper considered a variety of information sources on high temperature material applications. These sources included NRC regulatory guidance, insights from NRC public meetings, industry standards, historical modular HTGR licensing and pebble bed modular reactor licensing documents, ASME codes and code cases, and other sources related to gas-cooled reactors. Using these information resources, primary white paper objectives consisted of:

- Summarize existing policies and guidance that apply to HTGR materials
- Describe an approach for selecting materials, identifying properties, qualification, and accepting materials for key gas-cooled reactor components
- Discuss the influence material selection and code requirements have on LBEs and DBAs
- Discuss needed codes and standards work and note the status and schedule for code and standards activities already in progress.

The paper requested NRC staff agreement with the recommended approach to qualification and regulatory acceptance of materials for HTGR high-temperature service conditions.

Interactions and Outcomes

The NGNP High Temperature Materials White Paper was submitted to NRC on June 25, 2010. A follow-on public meeting held on September 1, 2010 to explain the white paper.

Based on NRC staff review of the white paper, additional information and clarifications were requested in NRC Letter No. 004, "The NGNP High Temperature Materials White Paper."[82] NRC issued 108 RAIs in the areas of high-temperature metals, graphite, carbon composites and ceramic insulation. These RAIs were responded to in a letter dated September 27, 2011.[83]

In a letter dated May 9, 2012, NRC issued a staff assessment of NGNP submittals concerning high temperature materials."[84] The document outlined NRC staff working group opinions on a wide variety of NGNP materials-related activities. Examples of that discussion included a concern about graphite irradiation at temperatures ranging from 250–600°C, aging issues associated with composite systems, and questions regarding the manufacture and qualification of nuclear-grade graphite. NRC staff further stated an intention to not provide final conclusions regarding the design and qualification of any NGNP components, materials, or their use in the plant design, until such time as an NGNP COLA or DC application is submitted.

Revision 1 of the NGNP High Temperature Materials White Paper[81] was issued in August 2012 and incorporated pertinent changes produced by NRC interactions and issuance of NRC assessment findings. However, the NRC assessment report clearly noted that as long as the NGNP plant resides at the conceptual stage of design and the materials to be used in key plant systems remain unconfirmed, the staff will not make a final acceptance decision on issues relating to material utilization. Resolution to specific material acceptance issues and the appropriate ASME Codes and Standards to be applied must be resolved during the COLA or DC application phase of the project.

5. VERY HIGH-TEMPERATURE REACTOR RESEARCH AND DEVELOPMENT ACTIVITIES

Very high-temperature reactor (VHTR) R&D activities were initiated in 2002 to support of DOE Generation IV Reactor Program. When the EPAct of 2005 directed DOE to begin NGNP, the VHTR R&D effort was recast as the NGNP Technology Development Program, conducted under the VHTR Technology Development Office (TDO).

Because of this change, the VHTR R&D effort was organized into three major elements:

- Fuel Development and Qualification – Nuclear fuel development, characterization, and qualification
- Materials Testing and Qualification – Materials selection, development, testing, and qualification
- Design Methods and Validation – Analytic methods development for reactor and balance-of-plant performance and safety analysis, execution of experiment benchmarks, and verification and validation of the analytic tools.

These initiatives each represented an important and ongoing source of information and data essential for successfully obtaining a NRC license for NGNP. Multiple NGNP technology development program plans were then prepared to describe technology development efforts in each of the three research areas. Each plan has been updated since initial issuance. The most recent revisions of the plans are:

- "Technical Program Plan for the Very High Temperature Reactor Technology Development Office/Advanced Gas Reactor Fuel Development and Qualification Program," PLN-3636, Rev. 3, May 5, 2014.[85]
- "Graphite Technology Development Plan," PLN-2497, Rev. 1, October 4, 2010[86]
- "Next Generation Nuclear Plant Reactor Pressure Vessel Materials Research and Development Plan," PLN-2803, Rev. 1, July 14, 2010[87]
- "Next Generation Nuclear Plant Steam Generator and Intermediate Heat Exchanger Materials Research and Development Plan," PLN-2804, Rev. 1, September 23, 2010[88]
- "Next Generation Nuclear Plant Methods Technical Program Plan," PLN-2498, Rev. 3, December 21, 2010.[89]

Each document addresses specific aspects of technology development necessary to support the regulatory approaches taken by NGNP prelicensing. Execution of the plans is controlled according to conditions specified in PDD-172, "Next Generation Nuclear Plant Quality Assurance Program Description," (QAPD)[90] and are represented in NGNP white papers as they relate to HTGR licensing framework development. The QAPD is discussed in in Section 5.6.

The following discussions summarize NGNP technology development plans and the NGNP QAPD.

5.1 Reactor Fuel Development and Qualification

Because of its role in functional containment, TRISO fuel is an important part of the NGNP licensing strategy. Thus, the AGR Fuel Development and Qualification Program is a critical component in demonstrating the ability of TRISO fuel to perform as intended by reactor design.

The program is focused on qualification of TRISO-coated particle fuel for use in modular HTGRs. The AGR Fuel Development and Qualification Program was established and is operated with the following overall goals:

- Provide a fuel qualification data set in support of licensing and the operation of an HTGR. HTGR fuel performance demonstration and qualification comprise the longest duration R&D task for HTGR design and licensing. The fuel form is to be demonstrated and qualified for service conditions enveloping normal operation and potential accident scenarios.

- Support deployment of HTGR for hydrogen and energy production in the U.S. by reducing market entry risks posed by technical uncertainties associated with fuel production and qualification.
- Extend the value of DOE resources by using international collaboration mechanisms.

The AGR Fuel Development and Qualification Program involves five major program elements: (1) fuel fabrication, (2) fuel and material irradiation, (3) fuel post-irradiation examination and safety testing, (4) fuel performance modeling, and (5) fission product transport and source term. Each program element is discussed in PLN-3636. These program elements directly support the approach to fuel qualification and to mechanistic source terms as described in Section 4.

As noted in a recent NRC staff assessment (ML14174A845) and discussed in Section 4.1, the AGR Fuel Development and Qualification Program is in the process of addressing many concerns of the staff developed during their evaluation of the Fuel Qualification and Mechanistic Source Terms white papers.[35,37] However, certain follow-up issues may be require additional attention by applicants after the AGR program is concluded.

5.2 Graphite Technology Development

The characterization, manufacture, and use of graphite for the HTGR is a topic of significant interest to NRC staff. While the characteristics of nuclear grade graphite are understood, historic grades of "nuclear" graphite are no longer available. Therefore, new grades of graphite must be fabricated, characterized, and irradiated to demonstrate that current production sources of nuclear-grade graphite exhibit acceptable non-irradiated and irradiated properties upon which the thermo-mechanical design of NGNP structural graphite is based. PLN-2497 outlines R&D activities and associated rationales necessary to qualify nuclear grade graphite for use in NGNP.

The construction of a commercial graphite-moderated HTGR requires re-establishment of a nuclear graphite supply chain that includes reliable coke sources, experienced graphite manufacturers, and the generation of sufficient quantities of graphite with properties and environmental effects data adequate to facilitate graphite core design and licensing. The acquisition of these quantitative data is the primary goal of the NGNP graphite R&D program.

The overall objectives to be met when qualifying graphite for initial NGNP operation are:

- Establish statistical non-irradiated thermo-mechanical and thermo-physical properties
- Characterize batch-to-batch and billet-to-billet variations (for probabilistic baseline data needs)
- Establish irradiated thermo-mechanical and thermo-physical properties
- Develop understanding of life-limiting phenomena at high dose and temperature (irradiation induced creep)
- Develop appropriate constitutive relations
- Establish reliable, predictive thermo-mechanical finite element models
- Establish relevant American Society for Testing and Materials (ASTM) standards and ASME design rules.

PLN-2497 details the specific material characterization techniques necessary to characterize the graphite microstructure and establish key material properties for both non-irradiated and irradiated specimens that support ASME codification of graphite. Factors that can impact the R&D program such as graphite acquisition, test standard development, and sample preparation (grain sizes, sample sizes, etc.), are discussed within each characterization section. Additionally, the role of modeling activities from engineering-scale to micro- or meso-scale to nano-scale, are discussed in the context of the qualification program and the interrelationship between experimental and modeling activities. These are presented to establish a complete picture of the technology development required for NGNP graphite qualification.

PLN-2497 also noted that a more complete evaluation of the processing route and raw material constituent influence on graphite behavior is necessary for full long-term HTGR graphite commercialization. A strategy was developed to address qualifying current and future batches of graphite type, development of future grades of graphite, and appropriate graphite recycling and disposal options. As graphite raw materials (coke and binder sources) continuously change, how these changes are assimilated into qualification activities still needs to be defined. In addition, nuclear graphite recycling needs to be addressed to reduce the burden of waste disposal.

5.3 Pressure Vessel Materials Research and Development

Operating conditions in HTGRs represent a major departure from LWR conditions. Because maintaining reactor pressure vessel (RPV) integrity is essential to safe and reliable HTGR operations, the materials used in pressure vessels are of major concern during license application review.

Relatively few choices exist for metallic alloys under nominal HTGR conditions, and the design lifetime considerations for metallic components directly impact maximum operating temperature. Qualification of materials for application at high-temperature conditions and a 60-year design life is an important focus of the NGNP materials R&D program effort.

Selection of NGNP design configuration must consider both cost and risk profiles to ensure that the demonstration plant provides a sound foundation for subsequent plants. The challenge is to achieve significant advancement in nuclear technology while setting the stage for economically viable large-scale commercial deployment. The Pressure Vessel Materials R&D Plan (PLN-2803) examines technical issues that must be resolved for NGNP licensing.

The following assumptions were incorporated into the plan:

- NGNP will be a full-sized reactor plant capable of producing process heat for various applications
- The reactor design will be a helium-cooled, graphite-moderated core design fueled with TRISO fuel particles in carbon-based compacts or pebbles
- The design, materials, and construction will need to meet appropriate quality assurance methods and criteria and other nationally recognized codes and standards. NGNP must demonstrate the capability to obtain an NRC operating license (OL)
- Modular HTGR plants will be designed to operate for a nominal 60-years
- Application for an NRC OL and fabrication of the NGNP will occur with direct interaction and involvement of one or more commercial organizations.

Studies of potential RPV steels were conducted as part of the pre-conceptual NGNP design. These studies generally focused on ASME code status of steels, temperature limits, and allowable stresses. Initially, three candidate materials were identified: conventional LWR RPV steels SA-508/SA-533, 2¼Cr-1Mo in the annealed condition, and Grade 91 steel. The low strength of 2¼Cr-1Mo at elevated temperature has eliminated this steel from candidacy as an RPV material.

Discussions with vendors capable of producing large forgings for nuclear pressure vessels indicate a strong preference for the conventional steels used in LWRs. This preference is largely based on extensive experience with forging these types of steels for nuclear components. It is also based on an inability to cast large ingots of Grade 91 steel due to segregation during ingot solidification, thereby restricting the mass of forged components and increasing the amount of welding required for the RPV. Grade 91 steel is prone to weld cracks and must be post-weld heat treated to ensure high-temperature strength. There are also questions about the ability to produce and verify thickness properties of thick sections of the Grade 91 material.

The commercial availability of a capacity to manufacture large components, issues dealing with ease of fabrication, and nuclear service experience with the SA-508/SA-533 steels strongly favor this material for use as a HTGR RPV material. Setting the helium coolant outlet temperature for NGNP at 750°C (as proposed in early conceptual studies) further strengthens the justification for using this material. Early selection of RPV steel reduces the need for further R&D tests and allows vendors with experience fabricating nuclear components to familiarize themselves with these materials and thereby reduce project risks.

The RPV materials technology development plan also details the R&D still required (assuming SA-508/SA-533 is the material of construction). The majority of required information is related to long-term aging behavior at NGNP vessel temperatures.

5.4 Steam Generator and Intermediate Heat Exchanger Materials Research and Development

Because NGNP will be a heat supply source for a variety of possible energy demand processes, NRC license application reviewers must thoroughly understand the means by which the thermal energy generated by the reactor core is transported to the external heat sink. According to PLN-2804, objectives of this program specifically relate to HTGR high-temperature applications addressing the steam generator, the intermediate heat exchanger (IHX), the core barrel and core internals such as control rod sleeves. Further research to improve design methodologies for high-temperature metallic alloys is also necessary. Performance data and models are inadequate for many high-temperature alloys that may be required by codes and standards, which are yet to be amended. Improved understanding is needed for the environmental effects and thermal aging of high-temperature alloys as well as welding and joining procedures and certification for various components including very thick plate and thin sheets. Inspection parameters must be defined and developed. The R&D plan also relies upon selected materials-related activities conducted at universities and international collaborations that benefit NGNP.

The materials R&D plan uses a baseline design case for NGNP and considers follow-on designs that may have higher outlet temperatures. The plan presumes the most likely design features and conditions as:

- An outlet gas temperature of 750°C
- A steam generator
- Possibly a heat exchanger with helium as both the primary and secondary coolant at a temperature up to 950°C
- A low pressure differential between the primary and secondary loops
- Consideration of section sizes typical of a conventional IHX and steam generator technology and thin sections that might be associated with compact designs.

The plan discusses technical issues that must be resolved for successful design and licensing of the steam generator and IHX for the NGNP and presents a detailed R&D plan, with associated cost and schedule, to resolve these issues. Materials issues associated with other high-temperature components in the reactor are also considered.

5.5 Design and Safety Methods Development

Both HTGR designers and license application reviewers rely extensively on analytical tools to perform necessary calculations and conduct appropriate analyses on systems that have bearing on the safety and performance of a new reactor technology. These tools must be developed, validated, and qualified for use in safety decisions that are essential to licensing. The NGNP Design Methods Development and Validation Program (i.e., Methods R&D) uses PLN-2498 to focus on tasks related to the development of key analytical tools necessary to assess neutronic and thermal fluid behaviors in a modular HTGR and to validate such tools can be used with confidence in making decisions related to reactor system safety and design performance objectives.

Methods R&D program activities are informed by provisions of NRC RG 1.203, "Transient and Accident Analysis Methods,"[91] which deals with qualification of evaluation models. R&D tasks are conducted to ensure that the calculational basis of the analytical tools under development for use in evaluating HTGR reactor systems fully encompass the operational and transient envelopes of anticipated system functions. Primary objectives of the NGNP Methods R&D program include:

- Defining the calculational envelope in which required HTGR reactor systems are to be objectively analyzed
- Defining an evaluation model capable of performing required calculations encompassed by the calculational envelope. This evaluation model must provide reference results against which licensee and regulator simulation results can be compared
- Designing and executing a matrix of thermal fluid experiments that produce a comprehensive data set against which the evaluation models developed by DOE, NRC, and HTGR vendors can be validated and verified.

Validation of thermal, neutronic, and fluid analysis codes relevant to HTGR analysis is still underway. Specific tasks include a series of fluid and heat transfer experiments that characterize phenomena and provide high quality data for use in validating new or modifying existing analysis tools. The data will also inform new physics analysis methods that account for heterogeneous core and fuel designs. These tools will address the nature of radiation transport in a graphite-moderated reactor. Results of these experiments and simulations are routinely published in INL external reports, conference papers, or articles in appropriate technical journals as they become available.

5.6 Next Generation Nuclear Plant Quality Assurance Program

The NGNP Technology Development Program is conducted under the provisions of the VHTR Quality Assurance Program.[92] Technology development is the primary activity conducted under this quality assurance (QA) program. The NGNP Quality Assurance Program Description (QAPD) document[90] establishes the quality assurance policy and requirements for the NGNP and assigns functional responsibilities for NGNP activities. It does this using methods and requirements that meet 10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants."

NGNP quality assurance requirements are nominally based on Regulatory Guide 1.28, "Quality Assurance Requirements (Design and Construction),"[93] and on Regulatory Guide 1.33, Revision 2, February 1978, "Quality Assurance Program Requirements (Operation)."[94] Regulatory Guide 1.28, Revision 4 states that Part I and Part II requirements of NQA-1-2008, 1a-2009, "Quality Assurance Requirements for Nuclear Facility Applications,"[95] provide an adequate basis for complying with the requirements of 10 CFR Part 50, Appendix B, subject to the additions and modifications identified therein. The NGNP QAPD is also based on the requirements and guidance of American Society of Mechanical Engineers NQA-1-2008, 1a-2009, Parts I and II, with specific reference to selected sections of Parts III and IV, as identified in the document. Industry guidance developed by the Nuclear Energy Institute (NEI), NEI 11-04, was used as a template for the NGNP QAPD.

On August 3, 2010, NGNP requested[96] that NRC review and endorse the NGNP QAPD to confirm that methods and requirements of 10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," were adequately addressed. An update to this submission was provided for staff review in PDD-172, Revision 3, in correspondence dated May 19, 2011.[97] On October 25, 2011, the NRC transmitted RAI's to NGNP in NRC Letter Number 06.[98] NGNP responded[99] on December 21, 2011 and clarified that while the QAPD described quality assurance requirements applicable to all aspects of NGNP, the scope of the review should focus on activities currently being performed and limited to technology development associated with the VHTR TDO.

On September 12, 2012, NRC issued a report titled "Staff Assessment of NGNP Quality Assurance Program Description"[100] concerning the contents of the NGNP QAPD, Revision 3, and related RAI responses. In this assessment, the staff confirmed their review covered only portions of the QAPD applicable to the current active scope of NGNP (i.e., non-applicant activities) and found that the program met the criteria of Appendix B to 10 CFR 50. The QAPD was considered acceptable for technology development and high-level design work.

The NRC assessment also conveyed a staff expectation for one of the following contingencies:

1. A supplemental QAPD would be submitted by INL, should the scope of the NGNP project be expanded to include design and/or construction activities that would warrant INL becoming an applicant in accordance with the guidelines of 10 CFR Part 52
2. Any future applicant or licensee planning to design and/or construct an NGNP-type reactor based on INL's current R&D efforts would submit an independent QAPD covering the planned scope of activities in accordance with applicable quality assurance regulations and guidance in place at that time.

In October 2012, INL issued Revision 5 of the QAPD which incorporated NRC inputs and assessment report comments. The QAPD will continue to be applied to NGNP technology development activities until it is accompanied by a license applicant's program as noted in Item 2 (above).

6. NEXT GENERATION NUCLEAR PLANT LICENSING FRAMEWORK

6.1 Attributes of the High-Temperature Gas-Cooled Reactor Regulatory Framework

On October 14, 2008, the Commission issued a revision to the NRC advanced reactor policy statement.[101] Besides reinforcing and updating previous policy statements regarding advanced reactors published in 1986 and 1994, this policy statement added a list of items to be considered during the design of advanced reactors.

> *"Regarding advanced reactors, the Commission expects, as a minimum, at least the same degree of protection of the environment and public health and safety and the common defense and security that is required for current generation light-water reactors [i.e., those licensed before 1997]. Furthermore, the Commission expects that advanced reactors will provide enhanced margins of safety and/or use simplified, inherent, passive, or other innovative means to accomplish their safety and security functions."*

This policy expectation was addressed during recent licensing actions for Generation III+ reactor designs (i.e., LWR designs such as the AP1000 and the economic simplified boiling-water reactor [ESBWR]) and is being communicated to other potential license applicants and stakeholders. The Commission Policy Statement is incorporated as a tenant in the NGNP licensing strategy and associated safety approach.

To license the initial demonstration HTGR plant, NGNP addressed the Policy Statement by working with the NRC staff to address existing regulatory requirements and approaches to provide for fuller integration of risk insights into the safety analysis. The goal was not to create a new regulatory framework expressly tailored to the needs of a HTGR but rather adapt existing LWR-oriented requirements in ways that meet Commission expectations for advanced reactor design with higher levels of technological neutrality.

Historically, a variety of approaches have been used to adapt LWR technical licensing requirements to advanced reactor designs. These approaches have generally employed deterministic methods. For instance, Fort St. Vrain (an HTGR located in Colorado) was licensed in the late 1960s and early 1970s using a traditional deterministic approach derived from adapted LWR requirements. Since the early 1990s and at Commission direction, however, probabilistic methods have been employed with increased preference. This resulted in overall movement towards use of risk-informed versions of traditional deterministic requirements. These approaches varied considerably in the extent to which probabilistic information are used in establishing a licensing basis.

NGNP advanced this trend by placing progressively greater emphasis on the use of risk insights and PRA techniques in the course of adapting and utilizing existing LWR requirements. Within the existing regulatory structure that supports licensing and using generic conceptual HTGR design information and previous HTGR licensing interactions as precedent, NGNP approached the establishment of NGNP licensing requirements by emphasizing:

- Identification and resolution (where possible, given existing uncertainties in the final design and license application development strategies) of significant policy, technical, and licensing issues relevant to HTGR COLA development, review and approval
- Identification of and engagement in prerequisite research that supports NGNP design advancement and COLA development and ensures NRC concurrence on technology development plans
- Engagement of reactor designers, potential applicants, industry, and DOE in essential pre-application interactions and coordinating those interactions with internal and external stakeholders

- Establishment of a HTGR training curriculum for the NRC staff
- Regulatory acceptance of a means to integrate risk insights into the licensing process and coupling those insights with deterministic engineering judgments to create a risk-informed, performance-based regulatory structure. This structure is amenable to the simplified, inherent and passive safety features associated with the modular HTGR design.

The proposed HTGR licensing framework is intertwined with a risk-informed regulatory approach predicated upon ongoing research, design, and safety analysis efforts. Additional issues for development, such as fuel transportation and storage, security and safeguards, and spent fuel disposal, are important to future applicants but were not addressed during NGNP prelicensing activities. This was primarily due to a lack of appropriate design detail and their priority relative to other licensing topics. Many of these issues are described in the NGNP Licensing Plan.[6]

6.2 Resuming High-Temperature Gas-Cooled Reactor Licensing Activities

6.2.1 Outstanding Next Generation Nuclear Plant Prelicensing Issues

This section discusses important NGNP licensing-related issues and topics that remain for resolution with NRC staff. The following items should be re-evaluated early in the COLA development cycle due to their potential impact on the scope and schedule of application submission. Some issues may not be resolved until adequate supporting design details become available.

Resolution of Issues Requiring Commission Guidance or Approval

NRC staff indicated that many aspects of the proposed NGNP approach are reasonable for use in future licensing actions. However, the staff also believes it is necessary to present some topics to the Commission for decisional action as a policy issue. This means the staff would likely ask NRC Commissioners for policy guidance before moving forward on the subject. Examples of such issues include:

- Approval of a complete set of DBAs for NGNP licensing
- Approval of specific reliability criteria to replace single-failure criteria for evaluating DBAs
- Use of the "per-plant-year" approach for addressing integrated risk at multi-reactor module plants
- Approval of cutoff frequencies within the various LBE categories
- Approval for use of realistic (mean) source term calculations for AE and BDBE TLRC compliance
- Approval of the approach for proposing a combined low population zone and EAB (or a scaled or reduced EPZ) partly based on event-specific release source terms calculated mechanistically for a spectrum of LBEs
- Endorsement of the proposed NGNP approach to fulfilling required functional containment performance standards.

Both NGNP and the ACRS questioned the staff concerning the need for Commission guidance on some of these issues during discussions held in early 2013. However, at this time, the topic of securing Commission policy determinations as a prerequisite to further staff action is unclear. Because the affected topics may significantly influence the scope and schedule of NGNP design decisions and application development, a plan of action should be established in conjunction with NRC staff to address key issues and secure necessary Commission actions early in the modular HTGR design and development process.

Adaptation of Regulatory Elements to Support License Application Development

The NRC/DOE 2008 Report to Congress[2] concluded that the NGNP licensing strategy should rely on an "Option 2" approach for adapting LWR-based technical requirements to reduce NGNP regulatory and licensing uncertainty. This option is to use deterministic engineering judgment and analysis, complemented by NGNP design-specific PRA information, to establish the licensing basis (including the selection of licensing basis events) and licensing technical requirements. Option 2 was chosen primarily to limit adverse impacts on the NGNP licensing schedule while providing consistency with the Commission Policy Guidance on the use of PRA.

"Option 3", a closely related path that was also evaluated by the joint working group and discussed in the 2008 Report to Congress, placed greater emphasis on the use of the NGNP design-specific PRA in complementing deterministic engineering judgment and analysis. While the NRC working group responsible for analyzing the NGNP regulatory approach agreed that either Option 2 or 3 provided a viable path for NGNP licensing, it was estimated that following Option 2 would require less time to complete. Readers should note, however, that since the two options are closely aligned, a clear differentiating between them requires a certain level of qualitative judgment.

While evaluating the RIPB process proposed by NGNP, NRC staff informally commented several times that "deterministic elements of the proposed approach should be strengthened." Further dialogue on the matter revealed that this feedback was provided not because the proposed NGNP process was intrinsically flawed but because the staff felt that that approach changes were needed to better align the process with their vision of Option 2.

The NRC staff suggested that deterministic elements could be strengthened by first identifying a set of LBEs (as is discussed in Section 4.1.2 of this report) and supplementing the DBA set by deterministically selecting additional bounding events to become DBAs. These additional events would be derived either from identified BDBEs or from other sources independent of the design-specific PRA.

NGNP believes that adopting this suggestion is inconsistent with the extensive NGNP-NRC interactions held regarding a defined and predictable process for event selection. NGNP considers that implementing the suggestion introduces excessive licensing uncertainty into the DBA identification process and moves in a direction different than the overall NRC movement toward increased use of risk insight.

In its May 15, 2012 letter[32] containing recommendations on NGNP licensing issues, the ACRS Full Committee found the staff's suggestion that a final DBA selection should include additional postulated deterministic event sequences to be inconsistent with the risk-informed framework proposed by NGNP. It also found the suggestion inconsistent with other on-going NRC activities encouraged by the Commission. The ACRS noted that although engineering judgment could be invoked to include postulated deterministic event sequences in the final selection of DBAs, if such sequences are not included in the PRA, the PRA is incomplete and should be revised to include them. These events could then be fully evaluated and appropriately considered for inclusion as DBAs according to the event category rules associated with implementing the risk informed approach.

The NRC staff position information on NGNP licensing approaches was issued on July 17, 2014.[48] The topic of LBE selection and the rationales supporting the process were not conclusively addressed in that document. Future license applicant(s) should therefore confirm early in the licensing process that the proposed risk informed approach to LBE selection is acceptable and assess whether it can be implemented within the licensing/deployment schedule of the project.

Refinement of Initial Power Ascension Testing and In-Core Monitoring Plans

During the application development process, the applicant will need to establish a precise description and thorough understanding of the full spectrum of testing, monitoring, and surveillance programs (including fuel surveillance and testing programs) and associated instrumentation systems envisioned to support initial power ascension testing and in-core monitoring plans for the first reactor module. A common understanding about the proposed approach should include early agreement with NRC staff regarding how the application will address the 10 CFR 50.43(e) regulatory requirements associated with nuclear reactor designs that differ significantly from LWR designs.

Plans for Establishment of Radionuclide Transport Models and Analyses

A clear understanding of the phenomena and mechanisms to be modeled for radionuclide transport from the primary helium circuit through the reactor cavity and its interconnected volumes, and from the reactor building, is needed for NGNP siting. A plan for addressing this topic should be defined through early dialogue with NRC. The plan should address how results of previous elicitations and reviews (PIRT, workshops, etc.) will be addressed in the key areas of moisture and air ingress, graphite dust effects (if any), and radionuclide deposition/re-entrainment from primary system surfaces (i.e., plateout and liftoff) under normal and off-normal HTGR conditions.

Establish Format/Content for SARRDL

An acceptable definition for a specified acceptable fuel design limit (SAFDL), or an appropriate alternative limit for coated particle fuel, remains to be established by HTGR designers and endorsed by NRC staff. During prelicensing discussions with NRC, NGNP staff observed that the SAFDL structure of LWR fuel is not meaningful to coated particle fuel. NRC staff acknowledged this issue before the ACRS on April 9, 2013 (ML13119A447).

During efforts to define appropriate PDCs for the HTGR (discussed in Section 3.2.5), NGNP determined that an alternative to the LWR-based SAFDL is necessary for proper alignment with the modular HTGR safety basis and the role of coated particle fuel. "Specified acceptable core radionuclide release design limit"(SARRDL) designates the proposed modular HTGR-specific regulatory limit for NGNP. The quantitative value of a SARRDL will be design specific and must be presented to NRC staff for review and acceptance.

6.2.2 Owner/Operator and Design Vendor Issues

The following discussion addresses additional issues of significance in NGNP licensing. It is recommended that designers and prospective owners/operators actively consider and address these issues prior to license application development.

Establish Final Licensing Approach Strategy

NGNP developed a strategic implementation plan for licensing derived from 10 CFR 52 requirements. From a design perspective, this means submittal of DC documentation can use preliminary design information and the Preliminary Safety Analysis Report (PSAR). If the Owner/Operator instead opts for a 10 CFR Part 50 licensing approach, the applicant needs to establish appropriate project schedules that reflects that alternative. This could potentially alter the approach to performing transient analysis from bounding event to specific event utilization.

Determine Extent of Fuel Proof Testing

The NGNP Fuel Acquisition Strategy[102] includes a fuel proof test from the production line at the Fuel Fabrication Facility used for final fuel qualification. Fuel is to be removed during the first few NGNP refueling periods and subjected to extensive post-irradiation examination and safety testing. The final proof test, however, is not part of the AGR Fuel Qualification Program and not included in the AGR Program Plan.

Discussions with the NRC staff on issues related to fuel qualification during the prelicensing review made clear the NRC's expectation that a proof test on fuel from the initial core should be performed to complete the fuel qualification effort. The staff took this position for two reasons:

1. AGR program test irradiations in the ATR reactor are not completely prototypical relative to neutron irradiation spectrum and accelerated time at temperature effects, particularly with regard to the relative number of plutonium fissions and the resulting effects on silver and palladium fission product yield and behavior
2. There will still be some, albeit minor, differences between the fuel fabrication process used for the AGR test fuel and the process used for the initial core fuel.

The extent of required fuel proof testing should be determined through additional discussions with the NRC staff by the Owner/Operator and Design Vendor team as early as possible.

Core Graphite Grade Selection and Development of Needed Data

The R&D effort, including data generation and development of ASME Boiler Pressure Vessel (BPV) Section III, Division 5 code rules for nuclear grade graphite, was significantly reduced in FY 2013. The Design Vendor will need to downselect the supplier and grade of graphite to be procured for the demonstration plant as early in the design process as practicable. This will allow focused R&D on that grade for materials properties testing. The testing needs to include irradiated graphite and detailed modeling of that graphite's heat transfer and oxidation behaviors. Engagement with ASME graphite code committees should be done as expediently as possible to ensure that the graphite data are appropriately incorporated into the ASME BPV code.

Specify Reactor Pressure Vessel Material

NGNP R&D and ASME BPV Section III code efforts have generally focused on SA-508/SA-533 as the material of choice for the vessel system (consisting of the reactor pressure vessel, cross vessel, and primary heat exchanger vessel). Alternative materials, however, such as Modified 9Cr-1Mo and 2.25Cr-1Mo steels, are also subject to consideration. If the demonstration plant's design direction changes to an alternative material, substantial R&D efforts may be necessary to develop qualified data and code information. Similarly, the sooner SA-508/SA-533 can be specified by the Design Vendor, the sooner code development and R&D efforts can exclusively focus on the material of choice.

Specify Heat Exchange Surface Material

Similar to the above discussion on reactor pressure vessel material, NGNP R&D and ASME BPV Section III code efforts have generally focused on Alloy 800H as the material of choice for heat exchange surfaces in the primary heat exchanger. This material would be used in the tubes of a steam generator. Alternative materials, however, such as Alloy 617 and 2.25CR-1Mo steel, can also be considered for use. An early decision on heat exchanger design and associated material will allow for acceleration in code development and R&D efforts to include fabrication/joining methods for the material of choice.

Determining Final Loop Configuration

Much of the conceptual NGNP design has focused on a plant configuration with a single, integrated primary loop. Should a future Owner/Operator and Design Vendor select a larger plant configuration with multiple loops, this change influences the plant footprint. Multiple loops also generate new design considerations involving mixed flows and transients that need to be addressed. Because of the fundamental impact on plant level assessments, the overall loop configuration should be specified very early in future design work.

Determine Plant Configuration and Couple Nuclear Island to Industrial Facility

The design efforts and feasibility studies conducted to date for NGNP typically treat the coupling of the process heat piping to the end user industrial facility as a black box. It is anticipated that the NGNP demonstration plant will be coupled to a yet undefined industrial application. When design work resumes, initial efforts should be directed at addressing the potential impacts that end-user requirements may have on final plant configuration and design. This could include various cogeneration configurations, impacts to power conversion system design, use of IHXs, and inclusion of tertiary loops for enhanced tritium control. The end user industrial facility and heat supply requirements may also affect key plant modeling and transient analysis.

Establish Design Data Needs

Once a final set of design requirements and plant configuration details are established, the Design Vendor will be able to establish a final set of design data needs (DDNs) to ensure technical and licensing considerations are captured and addressed. This will help to establish and focus the level of support needed by the DOE national laboratory complex to generate necessary data. Early identification and negotiation of DDNs is important to accomplish timely information turnaround times from the national laboratories and elsewhere.

Establish Level of Support for National Consensus Code Development

A substantial amount of support from various national standards and consensus codes organizations began during PBMR pre-application interactions with the NRC. This support was significantly expanded by actions taken through NGNP. However, recent cessation of NGNP design work has caused HTGR codes and standards support to diminish. When HTGR design work resumes, the Design Vendor is advised to evaluate what code support will be needed from national organizations and reestablish appropriate levels of engagement to accelerate and maintain momentum for code development according to desired COLA review schedules.

Instrumentation and Testing

In early assessments, NRC staff conveyed a belief that the applicant should establish a clearer understanding of the full spectrum of testing, monitoring, and surveillance programs and associated instrumentation systems envisioned for the NGNP prototype. In addition, DOE/INL should establish a shared understanding of how such programs could be used to facilitate effective resolution of technical issues both generally and in the context of prototype licensing provisions in accordance with 10 CFR 50.43(e)(2). Establishing such an understanding would require information on developing and deploying any advanced in-core detectors and an explanation how DOE/INL will calibrate and use measurement data to address technical specifications and verify and supplement the developmental technical bases for NGNP fuel qualification and mechanistic source terms.

Among the potential benefits that may result from bringing focused attention to this area in the near term would be the extra time afforded to develop and qualify advanced sensor and surveillance systems for HTGR service conditions.

6.2.3 High-Temperature Gas-Cooled Reactor Regulatory Gaps

As was discussed in Section 3.2.4, a suite of important operational and safety topics relevant to HTGR licensing have no counterpart in the LWR-oriented licensing structure used by the NRC. The nature of such topics is fundamental to nuclear safety and extensively treated in existing regulations and guidance relative to LWRs. However, the topics are addressed in a manner that cannot be applied to modular HTGRs. NRC regulations are largely silent on certain key issues germane to NGNP licensing and must be addressed if a HTGR COLA is be accepted by NRC staff for review.

Eight major gaps were identified concerning modular HTGR COLA development.[18] Although additional gaps may be identified as plant design decisions are finalized, the following topics are already recognized as a standing concern:

1. *HTGR fuel, design, and qualification*: Exacting specifications and consistent, repeatable performance associated with fuel qualification are a fundamental safety issue for the modular HTGR. The specific goals for HTGR fuel qualification are unique in that the fuel coating system is relied upon to contain fission products at very high temperatures. Although extensive progress has already been achieved

concerning NGNP fuel development and testing, results of this program remain to be presented to NRC staff for final review and acceptance.

2. *High-temperature ceramic materials (e.g., graphite), composites, reactor internal structures, and components design, manufacturing, inspection, and testing:* Current regulations and guidance are oriented toward the use of metallic core internals. The ASME code does contain provisions for qualifying alternative metallic materials for high temperature applications and must address non-metallic materials such as graphite. Code-approved non-metallic materials will be necessary for use in combination with metallic materials in HTGRs.

3. *Functional containment of radionuclide releases from the HTGR multiple barrier system:* The modular HTGR utilizes a "functional containment" concept and employs multiple barriers to fission product release and radionuclide transport. These serial barriers combine to limit the release of radionuclides to the environment. The concept of functional containment performance and its role in nuclear safety is not clearly recognized in existing regulations.

4. *Risk metric alternatives to core damage frequency and large early release frequency:* Core damage frequency (CDF) and large early release frequency (LERF) measures for LWRs are inappropriate risk metrics for HTGRs. Alternative risk metrics need to be established and validated if PRAs are used to support design and licensing.

5. *Guidance concerning the use of passive safety features:* Modular HTGRs use a safety-related passive heat removal system through appropriate design of the vessel system and reactor cavity cooling system. These systems, coupled with the TRISO-coated fuels' resistance to damage at high temperature, provide a mechanism for emergency core cooling that functionally addresses 10 CFR Part 50.46, GDC 34, and NUREG-800 Standard Review Plan (SRP), Chapter 6. However, there is little regulatory guidance available concerning performance standards and acceptance criteria for reactor passive safety features. HTGR passive safety features may require review and endorsement by the NRC concurrent with individual decisions related to passive safety design.

6. *Helium leakage and leak detection guidance:* The consequences of primary helium circuit leakage are different from those arising from a LWR primary coolant leak. A systematic approach to address these different risk elements and how consequences are mitigated requires further consideration.

7. *Safety classification for HTGR systems, structures, and components:* Functional safety classification is related to plant states under varying plant conditions. It is important to classify the safety significance level and associated quality, structural, seismic, control, and testing classes at each of the various conditions. While these actions are well established for LWRs, they will be quite different for HTGRs.

8. *HTGR accident analysis guidance:* Because the types of events, their classification, thermo-hydraulic transients, fission product behavior, mitigation, control functions and fission product barriers for HTGRs are different from LWRs, new regulatory guides are needed to support HTGR accident analysis.

6.2.4 Nuclear Regulatory Commission Standard Review Plan

RG 1.206 offers NRC approved guidance to authors of LWR COLAs. This guidance relies heavily on NRC requirements, acceptance criteria, and review standards prescribed in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants."[20] NRC license application reviewers rely upon the SRP as the basis for determining if a COLA is acceptable for initiating a licensing review. However, the SRP is currently not technology neutral and presumes a design approach derived from a standard large LWR power plant. Consequently, many SRP criteria cannot be applied to reactor technologies other than LWRs. Although NRC has indicated the SRP will eventually be adapted to accommodate advanced non-LWR technologies, the absence of a technology-compatible SRP may require development of groups of design-specific review plan (DSRP) documents to guide pre-application activities and aid NRC staff in license application reviews.

6.2.5 Developing Design Documents

As earlier noted in Section 1.2, NGNP design efforts were curtailed at the end of project "Phase 1." The NGNP plant currently stands at a conceptual level of design maturity. Despite this, certain aspects of the NGNP design approach are fairly well established.[103] However, there has been no plant level analyses (including PRA) to establish higher levels of overall design detail.

NGNP Regulatory Affairs engaged in pre-application interactions with the NRC to help identify programmatic policy issues that could ultimately affect final HTGR design efforts. These early interactions utilized design information that was understood at the time the interactions occurred; much of that information came from MHTGR pre-application interactions conducted in the 1980's and 1990's. When NGNP design work resumes, the design supplier will select a number of fundamental plant configuration options that add to the concept.

6.2.6 Collocated Facilities

Historically, commercial LWRs have been sited at considerable distance from industrial loads to isolate the risks industrial and nuclear operations may exert upon one another. This also isolated the regulatory obligations of a nuclear facility from corollary obligations that operate in non-nuclear facilities. Because a collocated HTGR heat supplier requires close physical placement (approximately a few hundred meters) to the industrial process heat sink, regulatory models must recognize and accommodate both the nuclear and non-nuclear compliance obligations at conjoined facilities. This issue may be even more problematic if the HTGR is sited in a "brownfield" setting with pre-existing chemical contaminations or share a common component of regulated infrastructure such as water and/or wastewater treatment facilities.

The nuclear island of a modular HTGR must conform to the terms and conditions of its NRC-issued license. However, these conditions will not normally be binding on an adjacent non-nuclear industrial facility. Similarly, the inverse may also be true concerning the industrial facility compliance posture. Depending on the nature of nearby industries, a web of local, state, and federal requirements may directly or indirectly encompass both facilities in ways not particularly obvious to the developers of a COLA at a collocated location. The issue of "jurisdictional authority" and "points of compliance" determinations for collocated nuclear/non-nuclear facilities should be addressed in a comprehensive regulatory compliance plan that considers and simultaneously addresses requirements of all linked facilities.

Issues that may be addressed in a collocated facility regulatory compliance plan include:

- Real-time ambient air monitoring and stack discharge abatement measures
- Solid/hazardous/radioactive waste management
- Wastewater treatment and discharge monitoring/control
- Accessibility for compliance monitoring and inspection
- Subsurface soil/groundwater water investigations and/or remediation
- Emergency response planning, training and drills
- Spill clean-ups and issues associated with legacy contamination.

There is limited precedence in establishing a complementary compliance model for NRC and non-NRC regulated facilities in a collocated setting. Early and comprehensive evaluations and the creation of a comprehensive compliance plan will be necessary if NRC license conditions are to be successfully coordinated with neighboring non-nuclear facility requirements derived from state and local government, court-ordered agreements, treaties, and regional criteria derived from statutes such as the Clean Water Act.

6.3 Other Prelicensing Insights

The following discussions transmit key NGNP prelicensing experiences, opinions and lessons-learned to future developers of HTGR COLAs and are provided in an advisory capacity.

6.3.1 Design-Specific Information

Significant historical and conceptual HTGR design information was available to support NGNP prelicensing interactions. However, many key design elements important to a comprehensive dialogue about the HTGR licensing framework were unavailable. Important details of the NGNP licensing approach could not be fully resolved because existing design information and performance data was inadequate. Examples of this insufficiency included the exact identity of engineered safety features, the role of the control room during adverse event sequences, the protection afforded control room operators, and credit given to the reactor building during radiological release consequence analysis. Absent such knowledge, NGNP staff relied on informed presumptions derived largely from historical information that may or may not reflect final design. It is recommended that all aspects of the HTGR licensing framework developed thus far be re-evaluated against the final NGNP design.

Had key elements of HTGR design been available during NGNP prelicensing interactions with the NRC, increased levels of NRC staff commitment may have accompanied the resulting regulatory positions. Absent such supporting information, however, NRC staff positions consisted of a determination about being “reasonable” or not rather than outright acceptance of a proposed approach. A determination of reasonableness is not the same as a legally-binding determination of acceptance by the NRC.

As a general rule, the NGNP prelicensing experience suggests that the higher the level of confirmed design information available to the staff during prelicensing interactions, a higher the level of regulatory certainty can accompany ensuing staff positions. Furthermore, it is also clear that unless prelicensing interactions include a prospective applicant that is actively involved in discussions and committed to submitting a COLA, NRC staff will be reluctant to fully endorse key licensing proposals. Without an announced applicant, NRC staff will generally seek to limit itself to advisory determinations.

6.3.2 Codes and Standards

Specification of approved national standards and consensus codes as part of the evolving NGNP design is important to timely COLA review. However, many codes and standards needed for NGNP design specifications are still in development, due in large part to the high temperature aspects of the HTGR. NGNP therefore actively supported development of various codes and standards deemed necessary to assure their maturity and completeness, approval, and issuance prior to development of key design specification documents. Summaries of this effort are included in INL/EXT-11-23907[103] and INL/EXT-10-19518.[104]

Developments in codes and standards continued following the FY 2012 reduction of NGNP support. This included the ASME/ANS Advanced Non-LWR PRA Standard that underwent review within the ASME/ANS Joint Committee on Nuclear Risk Management (JCNRM). However, the level of support for and the associated pace of development, review, and approval of these codes and standards has been degraded as a consequence of reduced development support.

The NRC has been consistently reluctant to endorse any new codes and standards for an HTGR until there is an application before them that includes a specification of the new codes and standards. The NRC has also expressed reluctance to endorse new codes and standards in a “piecemeal” fashion. This means applicants must direct attention to ensure appropriate support is available where proposed new codes and standards are established that support an application moving towards actual reactor deployment. The nominal turn-around time to resolve code issues through the governing organization and potentially revise and re-issue impacted COLA documents following the initial application could have an adverse impact on the COLA review period. There is currently considerable uncertainty regarding the total effort to resolve NRC issues with potential codes and standards, so this area is an area of substantial project risk. This matter should be discussed with NRC very early in the licensee's application process.

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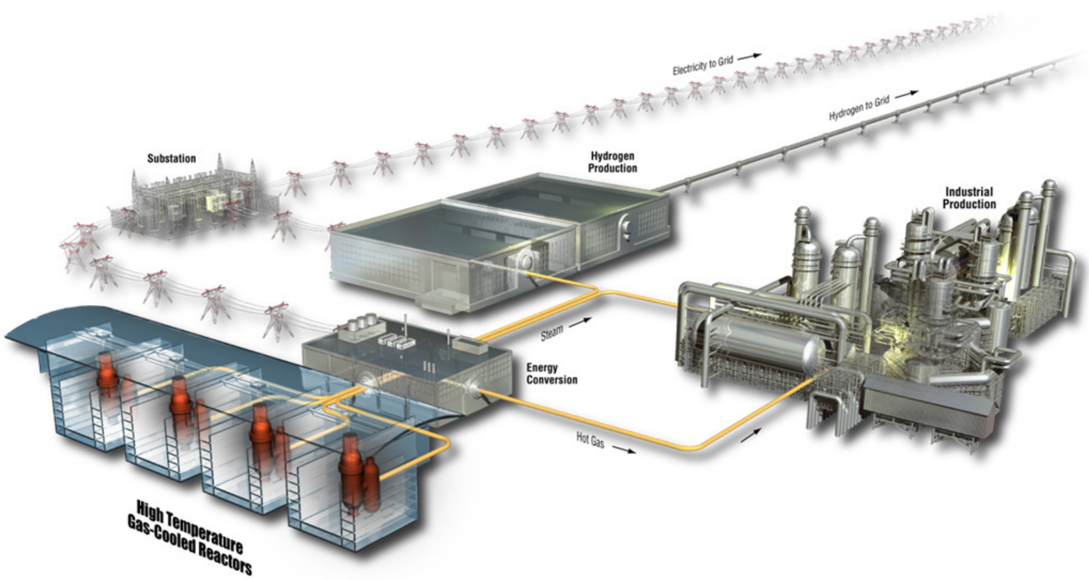
Appendix A

Next Generation Nuclear Plant White Papers



Appendix A
Next Generation Nuclear Plant White Papers

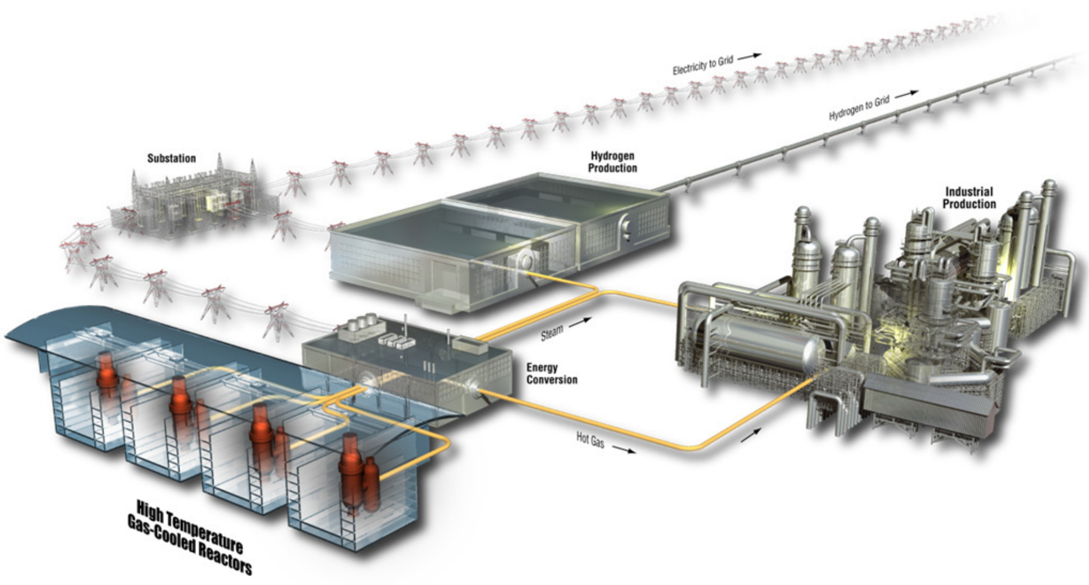
	White Paper	Submittal Date
1.	NGNP Defense-in-Depth Approach INL/EXT-09-17139	December 9, 2009
2.	High Temperature Materials White Paper INL/EXT-09-17187	June 25, 2010
3.	NGNP Fuel Qualification White Paper INL/EXT-10-18610 Revision 1	July 21, 2010
4.	HTGR Mechanistic Source Terms White Paper INL/EXT-10-17997	July 21, 2010
5.	Licensing Structure for Multi- Module Facilities INL/EXT-10-18178	August 10, 2010
6.	NGNP Licensing Basis Event Selection White Paper INL/EXT-10-19521	September 16, 2010
7.	NGNP Structures, Systems, and Components Safety Classification White Paper INL/EXT-10-19509	September 21, 2010
8.	Determining the Appropriate EPZ Size and Emergency Planning Attributes for an HTGR INL/MIS-10-19799	October 28, 2010
9.	NGNP Nuclear-Industrial Facility and Design Certification Boundaries INL/EXT-11-21605	July 22, 2011
10.	NGNP Probabilistic Risk Assessment White Paper INL/EXT-11-21270	September 20, 2011
11.	Modular HTGR Safety Basis and Approach INL/EXT-11-22708 (submitted for information only)	September 6, 2011

Appendix B

Next Generation Nuclear Plant Issue Resolution Worksheet Items

Appendix B
Next Generation Nuclear Plant Issue Resolution Worksheet Items

1.a., 1.b., and 1.c.



1.a. Functional Containment Performance Requirements for NGNP
Item 1.a. Confirm plans being implemented by the Advanced Gas Reactor Fuel Development and Qualification Program are generally acceptable and provide reasonable assurance of the capability of coated particle fuel to retain fission products in a controlled and predictable manner. Identify any additional information or testing needed to provide adequate assurance of this capability, if required. <u>Summary of NGNP Position</u> The NRC FQ/MST assessment report states: "The NRC working group's overall assessment is that the proposed high-level approaches to NGNP fuel qualification and mechanistic source terms are generally reasonable, albeit with several potentially significant caveats. This means that, subject to further consideration and resolution of details and issues noted subsequently in this assessment document, the working group's review of these white papers has found no fundamental shortcomings that would necessarily preclude successful implementation of the presented high-level approaches towards establishing the technical bases for related NGNP prototype licensing submittals." (Page 5, "Assessment of White Paper Submittals on Fuel Qualification and Mechanistic Source Terms," February 15, 2012.) NRC identified several-detailed technical follow up items to be addressed as the AGR Program and the NGNP design effort continue. These items are reflected in the FQ/MST follow up items EXCEL spreadsheet, which has been updated to reflect the results of discussions through the NGNP/NRC FQ/MST meeting of July 24, 2012. NRC has not, however, identified any additional information or testing needed directly from the AGR Program to provide assurance of coated particle fuel capability. NRC has indicated that proof testing of fuel fabricated in the production scale fuel fabrication facility will be required. This proof testing would be conducted in the NGNP initial core. Resolution of this matter will be an activity for the NGNP license applicant to pursue with the NRC. NGNP concurs with the working group's earlier conclusions that there are "…no fundamental shortcomings that would necessarily preclude successful implementation of the presented high-level approaches towards establishing the technical bases for related NGNP prototype licensing submittals." In addition, NGNP believes that progress toward closure has been made on several of the follow up items, and that some items can be closed at this time. See Attachment 1.a.
Requested Updates to Assessment Reports
Based on discussions of follow up items to date NGNP believes that the revised FQ/MST assessment report should contain changes to certain follow up items per the summary shown in Attachment 1.a. NGNP believes that the revised FQ/MST assessment report should reconfirm the acceptability of the AGR Program. This information should also be reflected in other documents being prepared by the staff to summarize the NGNP/NRC pre-licensing interactions.

Summary of Recent NRC Interactions
• Selected FQ/MST follow up items were discussed in an NRC public meeting on April 17, 2012. • Additional selected FQ/MST follow up items were discussed in an NRC public meeting on July 24, 2012. • Further dialogue on the topic, specifically on follow up item FQ/MST-19, was held during the NRC public meeting on siting source terms on September 20, 2012. • Summaries of notes, agreements, and actions resulting from the discussions of individual follow up items through September 20, 2012 are included in the FQ/MST items EXCEL spreadsheet.
Summary of Related Regulatory History
NUREG-1338, "Draft Preapplication Safety Evaluation Report for the Modular High Temperature Gas-Cooled Reactor," March 1989, pages 15-21 through 15-23. NUREG-1338, "Preapplication Safety Evaluation Report for the Modular High Temperature Gas-Cooled Reactor (MHTGR)," December 1995, pages 4-8 through 4-11. SECY-93-092, 1993, "Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and Process Inherent Ultimately Safe [PIUS]) and CANDU 3 Designs and Their Relationship to Current Regulatory Requirements," U.S. Nuclear Regulatory Commission, April 8, 1993.
Key NGNP References
"NGNP Fuel Qualification White Paper," INL/EXT-10-17686, Rev. 0, Idaho National Laboratory, CCN 221270, July 21, 2010. "Mechanistic Source Terms White Paper," INL/EXT-10-17997, Rev. 0, Idaho National Laboratory, CCN 221271, July 21, 2010. "Response to Nuclear Regulatory Commission Request for Additional Information Letter No. 002 Regarding Next Generation Nuclear Plant Fuel Qualification and Mechanistic Source Terms," CCN 224915, August 10, 2011. "Response to Nuclear Regulatory Commission Request for Additional Information Letter No. 003 Regarding Next Generation Nuclear Plant Fuel Qualification and Mechanistic Source Terms," CCN 225363, September 21, 2011. FQ/MST Follow Up Items Spreadsheet Following September 20, 2012 NRC Meeting.

Attachment 1.a.

NRC FQ/MST Assessment Report
Follow Up Items with Requested NRC Updates

FQ/MST-7, Fuel Performance Terminology

"The Project should establish explicit definitions with descriptive terms like defective, failed, and functionally-failed relative to fuel particles and individual coating layers and explain how fuel performance and radionuclide transport and release are considered and modeled in each case."

Definitions of intact, failed, functionally degraded, and defective particles were provided at the April 17, 2012, FQ/MST meeting, and the definitions were added to the follow up item spreadsheet. It was explained in the meeting that all known fuel performance phenomena are reflected in fuel performance models.

NGNP requests that NRC close out this item in their revised assessment report.

FQ/MST-14, Preirradiation Test Predictions

"The Project has not responded to the working group's RAI requesting pre-test predictions of the recently completed AGR-2 irradiation nor of any future AGR irradiations. The Project should freely share all test design and pre-test predictions of AGR irradiation conditions and irradiation fuel performance."

AGR-1 information and some AGR-2 information were transmitted to NRC in letter CCN 227952, dated July 19, 2012, and was provided informally on May 22, 2012, at the VHTR R&D FY12 Technical Review Meeting. Additional AGR-2 information will be provided in mid- to late-September.

NGNP requests that NRC update this item in their revised assessment report by deleting the first sentence, which implies a lack of cooperation on the part of the Project that was not intended.

FQ/MST-17, Applicability of Delayed Fuel Heating Tests

"To assess the effects of delayed testing on fuel particle performance, a quantitative comparison of the respective inventories of all elements produced by fission, activation, and decay would first be needed to determine any substantial elemental inventory differences. This would then be used to assess how the respective differences in elemental inventories could potentially affect fuel particle performance and how fuel performance could be affected by other changes in fuel composition (e.g., species migration, chemical reactions, phase changes) that might be expected to occur during extended periods of post-irradiation cooling and decay. Assessment of the applicability of delayed fuel heating tests to fuel performance in HTGR accident conditions is a follow-up item."

Detailed results of ORIGEN analyses of radionuclide decay in irradiated fuel particles was provided to NRC in letter CCN 227952, dated July 19, 2012. The analyses support the Project's position on this item.

NGNP requests that NRC close out this item in their revised assessment report.

FQ/MST-19, Determination of Bounding Source Terms

"The regulatory examination of DID capabilities (see Title 10 Code of Federal Regulations, Part 100 (10 CFR 100)) requires that a large release of radioactivity from the reactor coolant system to the reactor containment be hypothesized, consistent with expectations of a major accident at the reactor facility. This regulatory requirement is "technology neutral," predicated on the potential for severe events that could result in substantial releases of radioactivity from reactor fuel. The working group believes that BDBE's significantly more severe than those considered to date in the white papers on MST and LBE selection should be evaluated for calculating bounding source terms. The Project is correct in noting that the LWR oriented containment source term definition invoking a severe accident with extensive fuel melting is not applicable to modular HTGRs. The definition more pertinent to modular HTGRs would be the severe event induced releases to the reactor building and to the environment of (a) radionuclides released from fuel elements resident in the core during the accident and (b) long-lived radionuclides that have gradually accumulated in the primary system over many years of normal operation. The Project's definition of event-specific mechanistic source terms for the HTGR is generally consistent with the traditional staff definitions. However, the working group believes that appropriate consideration should be given to all available barriers in the assessment of event-specific mechanistic source terms."

This item has been briefly discussed in RIPB and functional containment meetings and was discussed further in a meeting in a meeting on September 20, 2012. In the April 17, 2012 FQ/MST meeting, the NRC staff stated that the siting source term requirements are not really "technology neutral", as noted in the published meeting summary.

NGNP requests that NRC revise this item in their revised assessment report by deleting the statement that the siting source term requirements are "technology neutral". NGNP also requests that the outcome of interactions regarding the approach to siting source terms, including those following the September 20 meeting, be reflected in the revised assessment report. NGNP also believes that it has made it clear in discussions with the NRC that it gives full consideration to all of the barriers of the functional containment is its assessment of event-specific mechanistic source terms. Accordingly, NGNP requests that NRC delete the last sentence of this follow up item in its revised assessment report.

FQ/MST-24, Models and Data for Fuel Particle Performance During Normal Operation and Heat-up Accidents

This issue contains 13 detailed sub-issues regarding the details of the Goodin-Nabielek model for coated fuel particle performance under normal operating and accident conditions.

During the July 24, 2012, FQ/MST meeting the Project stated that the Goodin-Nabielek model may not be used by the NGNP applicant and recommended that this follow up issue be updated to reflect this possibility. NRC agreed to update the item to focus it on fuel performance models in general rather than the Goodin-Nabielek model specifically.

NGNP requests that NRC revise the item in the revised assessment report as agreed in the meeting.

FQ/MST-29, Long Term Modeling of Radionuclide Transport within the Core and the Reactor Coolant System

“A great deal of discussion is provided in the white papers on experiments and modeling radionuclide release from the fuel. However, much less discussion is given to source term model development and verification beyond the fuel such as transport in the reactor system and behavior following release from the reactor system. Indeed, a major challenge in the accident analysis of modular HTGRs is the modeling of radionuclide transport within the core and the reactor coolant system over many years of normal plant operation before initiation of an accident or transient. This is an item for follow up.”

During the July 24, 2012, FQ/MST meeting NRC indicated that it would like to receive additional information regarding which radionuclides are expected to be the predominate contributors to offsite doses for various HTGR accident sequences. NRC would also like information on the relative inventories of these isotopes that are expected to be present in the core, in the helium coolant or plated out on helium pressure boundary surfaces, released to the reactor building, and released to the environment under various accident sequences. NRC stated that this information would help it understand the mechanistic source term approach. The information was provided in NGNP Letter to NRC CCN 228482, September 20, 2012.

During the July 24 meeting, NGNP indicated that the third sentence of this follow up item is not technically correct, in that the determination of radionuclide behavior over the design life of the plant is no more technically challenging than doing so over shorter operation times. NGNP also noted that predictions of radionuclide behavior in earlier HTGRs such as Peach Bottom and Fort St. Vrain were shown to be conservative and within the allowable uncertainties. Based on those discussions, NGNP requests that NRC revise this item in the revised FQ/MST assessment report by deleting the third sentence of the item.

FQ/MST-32, Impact of Dust on the Behavior of Fission Products

“The working group questions the Project’s confidence in the analytical results when not much is known about the dust behavior, and believes the analytical effort needs to be complemented with experimental plans. This is an item for follow up.”

FQ/MST-37, Effects of Dust on Fission Product Transport

“The HTGR dust workshop in March 2011 produced a document that describes potential HTGR dust safety issues as well as research and development needs, based upon the discussions at the workshop. What is missing in the document is a substantive discussion on what to do with the findings of the workshop. Again, the working group views this as a necessary first step in developing and validating fission product transport models which incorporate the contribution of dust. This is an item for follow up.”

During the July 24, 2012, FQ/MST meeting NGNP stated that the degree to which dust is produced in HTGRs with prismatic fuel is, based on historical data, significantly less than that for pebble bed designs. NGNP requested that the NRC assessment report be revised to note this distinction, and NRC agreed to revise the report accordingly. NRC stated that future work on prismatic designs should include analyses to support the case for dust effects in those designs being negligible.

NGNP requests that NRC revise these items in the revised assessment report to reflect the discussion and agreements reached in the meeting.

FQ/MST-38, Uncertainty Models

“The working group notes that the Monte Carlo uncertainty analysis proposed by the Project appears to address only parametric uncertainty. The regulatory community recognizes also “model uncertainty” and “completeness uncertainty”. There is, of course, no practical way to quantify completeness uncertainty (“unknown unknowns”). There is, however, a growing trend of asking at least for some assessment of model uncertainty if not rigorous quantification of this uncertainty. This is an item for follow up.”

In the April 17, 2012, FQ/MST meeting, NGNP agreed to submit a description of how it proposes to assess “model uncertainty”. It was agreed that no further action is required regarding “completeness uncertainty”. The information on “model uncertainty” was provided by NGNP Letter to NRC CCN 228482, September 20, 2012.

NGNP requests that the NRC revise this item to reflect the agreement that “completeness uncertainty” need not be further addressed. NGNP would like the revised assessment report to reflect the information on “model uncertainty” provided in September and, if possible, to close out this item.

FQ/MST-40, Analyzing Mechanistic Source Terms for Specific LBE Categories

“To bound severe accidents, it is the working group’s view that events ranging in frequency from 10-5 to 10-8 per reactor-year should also be considered for the purpose of siting and containment system design decisions. Events in that frequency range are defined by the Project as BDBEs. Where events in the frequency range of 10-5 to 10-8 per reactor-year are considered for the purpose of siting and containment decisions (i.e., to ensure defense-in-depth is provided by the containment system design), a conservative analysis may thus be required. The working group believes that a Commission policy decision may be needed to support a final determination on how events in that frequency range will be considered for the purpose of siting and containment system design decisions (i.e., containment system design defense-in-depth). This is an item for follow up.”

Many of the issues in this follow up item (LBE frequency ranges, siting source terms, and containment design) have been addressed in various meetings covering the risk informed performance based process, and meetings on functional containment. Additional discussions on siting source terms were held in a meeting with the NRC on September 20, 2012.

NGNP requests that NRC update this item in the revised assessment report to reflect the agreements reached in those discussions.

FQ/MST-41, Peer Review of NGNP Mechanistic Source Terms

“The reference draft ASME/ANS PRA standard states that it is required that all PRA elements (including the mechanistic source term element) have a peer review. The need for a peer review of the NGNP mechanistic source terms is thus considered an item for follow up.”

In the April 17, 2012, FQ/MST meeting the Project committed to peer review of all PRA elements and independent review of safety analyses. This includes source term calculations.

NGNP requests that NRC close this item in the revised assessment report.

1.b. Functional Containment Performance Requirements for NGNP
Item 1.b. Establish options regarding functional containment performance standards as requested by the Commission in the Staff Requirements Memorandum (SRM) to SECY-03-0047, "Policy Issues Related to Licensing Non-Light Water Reactor Designs," and discussed further in SECY-05-0006, "Second Status Paper on the Staffs Proposed Regulatory Structure for New Plant Licensing and Update on Policy Issues Related to New Plant Licensing." <u>Summary of NGNP Position</u> The upper tier performance standard for the functional containment is to assure the integrity of the fuel particle barriers (i.e., the kernel and coatings of the TRISO coated fuel particles) rather than to allow significant fuel particle failures and then need to rely extensively on other mechanistic barriers (e.g., the reactor coolant pressure boundary and the reactor building). This standard is characterized by: • Radionuclide retention within fuel during normal operation with relatively low inventory released into the helium pressure boundary (HPB). • Limiting radionuclide releases to the environs to meet the onsite and offsite radionuclide dose acceptance criteria (i.e., 10 CFR 50.34 and EPA PAGs) at the Exclusion Area Boundary with margin for a wide spectrum of off-normal events. • Maintaining the capability to establish controlled leakage and controlled release of delayed accident source term radionuclides. An additional set of functional containment performance standards, already accepted by the staff in SECY-05-0006, is to directly or indirectly accomplish the following accident prevention and mitigation safety functions: • Protecting risk-significant SSCs from internal and external events. • Physically supporting risk-significant SSCs. • Protecting onsite workers from radiation. • Removing heat to prevent risk-significant SSCs from exceeding design or safety limits. • Providing physical protection (i.e., security) for risk-significant SSCs.
Requested Updates to Assessment Reports
RIPB Assessment Report – Section 2.1.2, Ps. 10 and 11: NGNP requests that the following excerpt from this assessment report be revised to reflect the NGNP position that the descriptions of the functional containment and the performance standards stated above are reflected in the MST paper and have been discussed in presentations to the NRC staff during recent public meetings to demonstrate the inherent defense-in-depth capability of the functional containment. "Neither the NGNP LBE White Paper nor the NGNP MST white paper identified an approach or criteria for demonstrating the defense-in-depth capability of the functional containment system."

Summary of Recent NRC Interactions
• May 16, 2012, public meeting with NRC in Rockville, MD. • July 10 and 11, 2012, public meetings at NRC in Rockville, MD.

Summary of Related Regulatory History
• SECY-93-092, "Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and PIUS) and CANDU 3 Designs and Their Relationship to Current Regulatory Requirements" page 11: – "The staff proposes to utilize a standard based upon containment functional performance to evaluate the acceptability of proposed designs rather than to rely exclusively on prescriptive containment design criteria." – "Containment designs must be adequate to meet the onsite and offsite radionuclide release limits for the event categories to be developed as described in Section A to [SECY-93-092] within their design envelope." • SECY-95-299 "Issuance of the Draft of the Final Pre-application Safety Evaluation Report (PSER) for the Modular High-Temperature Gas-Cooled Reactor (MHTGR)" [NUREG-1338, December 1995 – "…the Commission decided that a conventional LWR, leak tight containment should not be required for advanced reactor designs. It approved the use of containment functional design criteria for evaluating the acceptability of proposed containment designs rather than the use of prescriptive design criteria" (pages 4-11). – "The position regarding containment allows the acceptance of containments with leak rates that are not "essentially leak tight" as described in GDC 16 for LWRs" (pages 5-10). • SRM to SECY-03-0047, "Policy Issues Related to Licensing Non-light-water Reactor Designs" page 2: • The Commission disapproved the staff's recommendation related to the requirement for a pressure-retaining containment building, stating that there was insufficient information for the Commission to prejudge the best options and make a decision on the viability of a confinement building, but directed the staff to pursue the development of functional performance standards taking into account such features as core, fuel, and cooling systems design and then submit options and recommendations to the Commission on this issue. • 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" • "The safety philosophy is to assure the fuel containment barrier rather than to allow significant fuel failures and then have to rely extensively on either backup barriers (such as a containment) or other mechanistic barriers associated with the core graphite structures or reactor coolant pressure boundary." (Attachment 4, page 1) • Of the options evaluated, the staff endorsed the position that "The containment must adequately reduce radionuclide releases to the environs to meet the onsite and offsite radionuclide dose acceptance criteria for the events selected for the event categories and have the capability to establish controlled leakage and controlled release of delayed accident source term radionuclides." (page 7)

• “The staff has concluded that the function of containment has a direct or supporting role in the following accident prevention and mitigation safety functions: • Protecting risk-significant SSCs from internal and external events. • Physically supporting risk-significant SSCs. • Protecting onsite workers from radiation. • Removing heat to prevent risk-significant SSCs from exceeding design or safety limits. • Providing physical protection (i.e., security) for risk-significant SSCs. • Reducing radionuclide releases to the environs and limiting core damage.”
Key NGNP References
• July 11, 2012, NGNP presentation to NRC staff and associated meeting notes on functional containment.

1.c. Functional Containment Performance Requirements for NGNP

Item 1.c. Establish a staff position to support a final determination regarding how LBEs will be considered for the purpose of plant siting and functional containment design decisions, taking into consideration previous staff positions in SECY-95-299, that improved fuel performance is a justification for revising siting source terms and containment design requirements. In particular, we request that this staff position provide an adaptation of the guidance that has generally been applied to light water reactors (LWRs) for compliance with 10 CFR 100.21. (It is noted that for LWRs, this guidance has typically included the assumption of a substantial meltdown of the core with the subsequent release of appreciable quantities of fission products.) The NRC's development of the NGNP adaptation of this guidance, which should reflect the NGNP's unique event response characteristics, will rely heavily on the establishment of the NRC staff positions associated with Licensing Basis Event Selection and Establishing Mechanistic Source Terms.

<u>Summary of NGNP Position</u>
With respect to defining the siting source term (SST) that will be used in the siting analyses (10 CFR 100.21) and functional containment performance evaluations, the fission product release assumed should be based upon a spectrum of risk informed, mechanistically evaluated events over the LBE-spectrum that have limiting consequences and will take into account the safety behavior of the plant. To assure that there are no cliff-edge effects and to understand the ultimate safety capability of HTGRs, supplement the LBE-derived SSTs with insights from a best estimate mechanistic evaluation of bounding event sequences, with understanding that:

- Such events shall be physically plausible rather than arbitrary combinations of event parameters or end-states, and
- Events and their evaluation will consider the intrinsic and passive characteristics, and the safety behavior, of the HTGR.

Furthermore, the assumptions underlying the bounding siting event for Light Water Reactors are not technology neutral, in that, HTGRs and their safety characteristics were not considered when the guidance in footnote "5" to 10 CFR 52.79(a) was developed. NRC confirmed this position in their meeting summary for the NGNP/NRC public meetings of April 16–17, 2012, consistent with the Statements of Consideration for 10 CFR Part 100, summarized below.

Therefore, it is concluded that modular HTGR's can be licensed to 10 CFR 52.79(a) including footnote "5" without exemption or change by rulemaking, based on an applicant's submittal of an acceptable SST alternative to the footnote "5" second sentence, using the process summarized above. It is recognized that the results of the implementation of this process may result in "non-core melt" SSTs for modular HTGRs.

Requested Updates to Assessment Reports
FQ/MST assessment report – Section 3.9, pages 27-28: NGNP requests that the following excerpt from this paper be revised to be consistent with the NGNP position described above and with the related NRC meeting summary of the NGNP public meetings held on April 16–17, 2012 (Accession No. ML12132A457): “The regulatory examination of DID capabilities (see Title 10 Code of Federal Regulations, Part 100 (10 CFR 100)) requires that a large release of radioactivity from the reactor coolant system to the reactor containment be hypothesized, consistent with expectations of a major accident at the reactor facility. This regulatory requirement is “technology neutral,” predicated on the potential for severe events that could result in substantial releases of radioactivity from reactor fuel.” “The working group believes that BDBE’s significantly more severe than those considered to date in the white papers on MST and LBE selection should be evaluated for calculating bounding source terms.” **RIPB assessment report** – Section 2.2.1, page 24: In the following excerpt from this paper, revise the first sentence to be consistent with NRC’s evaluation of the NGNP position above, as discussed during the public meeting on September 20, 2012, and the position in issue item 1.b, to state that the NGNP safety philosophy is to assure the integrity of the fuel containment barrier rather than to allow significant fuel failures and then have to rely extensively on backup barriers (such as a containment). This would include consideration of a revision to the last sentence in the excerpt to state that the regulatory requirement is predicated on a fission product release based upon a major accident and for the NGNP this major accident is based upon a spectrum of risk informed, mechanistically evaluated events over the LBE-spectrum that have limiting consequences and will take into account the safety behavior of the plant. “. . .the working group is not clear regarding the NGNP approach to the fourth criterion [require containment structures and safety features to prevent the release of fission products]. NRC’s regulations address this criterion in the requirements for evaluation of a hypothetical accident in 10 CFR 50.34 and 10 CFR 52.79, as discussed in the LBE white paper assessment above. This regulatory requirement is predicated on the potential for severe events that could result in release of appreciable quantities of fission products from reactor fuel.”
Summary of Recent NRC Interactions
• April 16–17, 2012, public meetings with NRC in Rockville, MD. • May 16, 2012, public meeting with NRC in Rockville, MD. • July 11, 2012, public meeting at NRC in Rockville, MD. • September 20, 2012, public meeting at NRC in Rockville, MD. • Summary of previous agreements and resolutions: – Siting source terms used for specification of acceptable LWR containment leak rate are not applicable to NGNP. – The NGNP definition of event-specific mechanistic source terms for the HTGR is generally consistent with the traditional staff definitions.

Summary of Related Regulatory History

- Statement of Consideration for original 10 CFR Part 100 rulemaking (27 FR 3509), page 3:
- "These guides and the technical information document are intended to reflect past practice and current policy of the Commission of keeping stationary power and test reactors away from densely populated centers. It should be equally understood, however, that applicants are free and indeed encouraged to demonstrate to the Commission the applicability and significance of considerations other than those set forth in the guides."
- 10 CFR Part 100.10:
- "In particular, the Commission will take the following factors into consideration in determining the acceptability of a site for a power or testing reactor:

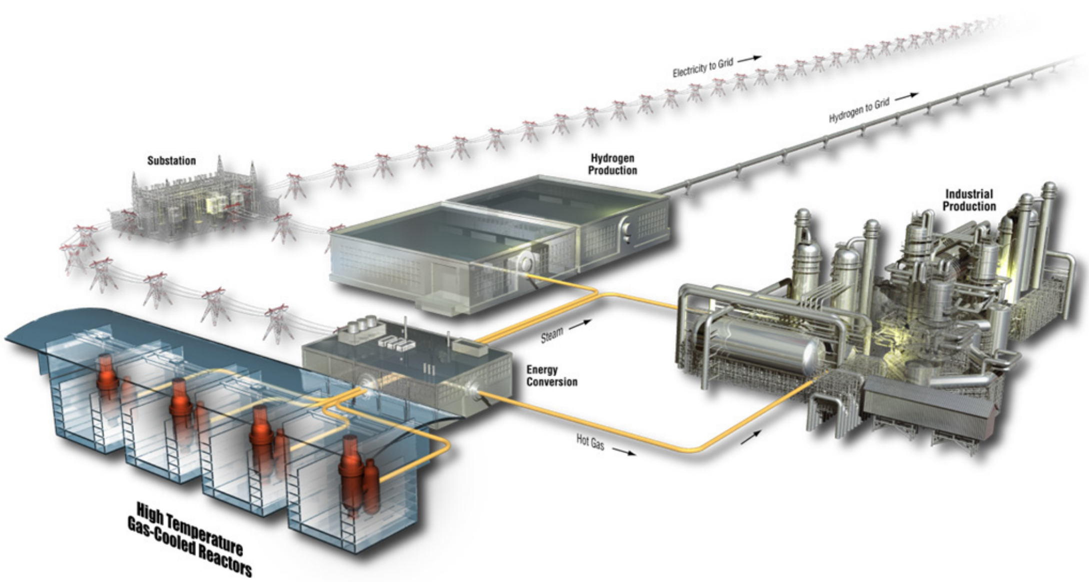
  (a) Characteristics of reactor design and proposed operation including:
  (4) The safety features that are to be engineered into the facility and those barriers that must be breached as a result of an accident before a release of radioactive material to the environment can occur."
- 10 CFR Part 100.11, note:
- "The calculations described in Technical Information Document 14844 may be used as a point of departure for consideration of particular site requirements which may result from evaluation of the characteristics of a particular reactor, its purpose and method of operation."
- SECY-93-092, "Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and PIUS) and CANDU 3 Designs and Their Relationship to Current Regulatory Requirements" page 11:
  - The staff proposes to utilize a standard based upon containment functional performance to evaluate the acceptability of proposed designs rather than to rely exclusively on prescriptive containment design criteria.
  - Containment designs must be adequate to meet the onsite and offsite radionuclide release limits for the event categories to be developed as described in Section A to [SECY-93-092] within their design envelope.
- NUREG-1338, "Draft Preapplication Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor," March 1989:
  - "In its review of the DOE's mechanistic approach, the NRC staff concluded that, for plant designs with long response times and the capability to withstand many low-probability events, it is acceptable and preferred to develop mechanistic bases rather than to follow the customary approach of postulating a non-mechanistic source term, which could obscure important phenomenological considerations." (Section 15.5)
  - "The NRC staff accepted DOE's proposed source term for use in the MHTGR conceptual design review." (Section 15.5)
  - "Final selection of SSTs for the MHTGR was to depend on factors such as the results of research programs and further safety analysis." (Section 15.6)

- SRM to SECY-03-0047, "Policy Issues Related to Licensing Non-light-water Reactor Designs," page 2:
  - The Commission disapproved the staff's recommendation related to the requirement for a pressure-retaining containment building, stating that there was insufficient information for the Commission to prejudge the best options and make a decision on the viability of a confinement building, but directed the staff to pursue the development of functional performance standards taking into account such features as core, fuel, and cooling systems design and then submit options and recommendations to the Commission on this issue.
- 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":
  - "The safety philosophy is to assure the fuel containment barrier rather than to allow significant fuel failures and then have to rely extensively on either backup barriers (such as a containment) or other mechanistic barriers associated with the core graphite structures or reactor coolant pressure boundary." (Attachment 4, page 1)
  - Of the options evaluated, the staff endorsed the position that the containment must adequately reduce radionuclide releases to the environs to meet the onsite and offsite radionuclide dose acceptance criteria for the events selected for the event categories and have the capability to establish controlled leakage and controlled release of delayed accident source term radionuclides. (page 7)

Key NGNP References

- NRC meeting notes from NGNP public meetings held on April 16–17, 2012 (Accession No. ML12132A457).
- July 11, 2012, NGNP presentation to NRC staff and associated meeting notes.
- September 20, 2012, NGNP presentation to the NRC staff.

Next Generation Nuclear Plant Issue Resolution Worksheet Items 2.a.-1, 2.a.-2, 2.a.-3, 2.a.-3, 2.a.-4, 2.a.-5, 2.a.-6, and 2.a.-7



2.a.-1 Licensing Basis Event Selection for NGNP

- Item 2.a.-1 Establish and endorse a structured, risk-informed, performance-based approach for selecting and categorizing licensing basis events as they may occur over a broad spectrum from normal operation to rare, off-normal events. The approach should address the concept of adequate protection through an appropriate balance between defense-in-depth and risk considerations. In developing staff positions on this approach, NRC is requested to:
- Agree with the placement of top-level regulatory criteria (TLRC) on a frequency-consequence (F-C) curve.

Summary of NGNP Position
The TLRC establish limits on the frequencies and public radiological consequences used to classify and evaluate licensing basis events (LBEs). These criteria provide the technical basis for ensuring that the design meets applicable top-level public health and safety regulatory criteria. The TLRC establish the quantitative, direct measures of public safety acceptance criteria, which must be met (see Attachment 2.a.-1).

Acceptable limits on event sequence consequences (for the associated LBE categories) are as follows:

- AEs – 10 CFR Part 20: 100 mrem total effective dose equivalent (TEDE) mechanistically modeled and realistically calculated at the exclusion area boundary (EAB).
- DBEs – 10 CFR §50.34/10 CFR §52.79: 25 rem TEDE mechanistically modeled and conservatively calculated at the EAB.
- BDBEs – NRC Safety Goal quantitative health objectives (QHOs) mechanistically and realistically modeled calculated at 1 mile (1.6 km) and 10 miles (16 km) from the plant.

These proposed limits, shown graphically in Figure 2.a.-1, are consistent with the limits presented in ANS 53.1.

Requested Updates to Assessment Reports

Staff agreed with Part 20 for AEs. 2.1.4 – page 16.

Staff agreed with Part 50.34 for DBEs. 2.1.4 – page 17.

Staff agreed with use of QHOs for DBEs and BDBEs. 2.1.4 – page 17.

Request that the "Summary of Findings" wording on page 18 be revised. The lead-in paragraph states that the "working group believes that the proposed F-C curve and associated dose calculation framework should be revised." This leads the reader to think that each of the summary items represent areas where the staff has disagreement with our approach. However, this list includes some items that the staff agreed were reasonable in the body of the assessment report.

Example: (3rd bullet) "Acceptable DBE doses should be derived from regulatory limits given in 10 CFR 50.34 and 10 CFR 52.79 (i.e., 25 rem TEDE)." That is consistent with our proposal, so wording should be included to say it is acceptable (like the following bullet). The 5th bullet should also be revised based on the same comment.

Summary of Recent NRC Interactions
• April 16, 2012, public meeting with NRC in Rockville, MD. • May 16, 2012, public meeting with NRC in Rockville, MD. • August 22, 2012, publically noticed conference call requested agreements and resolutions. • September 19, 2012, public meeting with NRC in Rockville, MD.
Summary of Related Regulatory History
• NUREG-1338, Section 3.2.2.1 – Accident Selection, March 1989. • SECY-03-0047, Policy Issues Related to Licensing Non-Light-Water Reactor Designs, Issue 4.
Key NGNP References
• “Next Generation Nuclear Plant Licensing Basis Events Selection White Paper,” INL/EXT-10-19521, CCN 222013, September 16, 2010. • April 16, 2012, NGNP presentation to the staff and related meeting summary. • May 16, 2012, NGNP presentation to the staff and related meeting summary. • August 22, 2012, NGNP presentation to NRC staff. • September 19, 2012, public meeting with NRC in Rockville, MD.

Attachment 2.a.-1

NRC FQ/MST Assessment Report
Follow Up Items with Requested NRC Updates

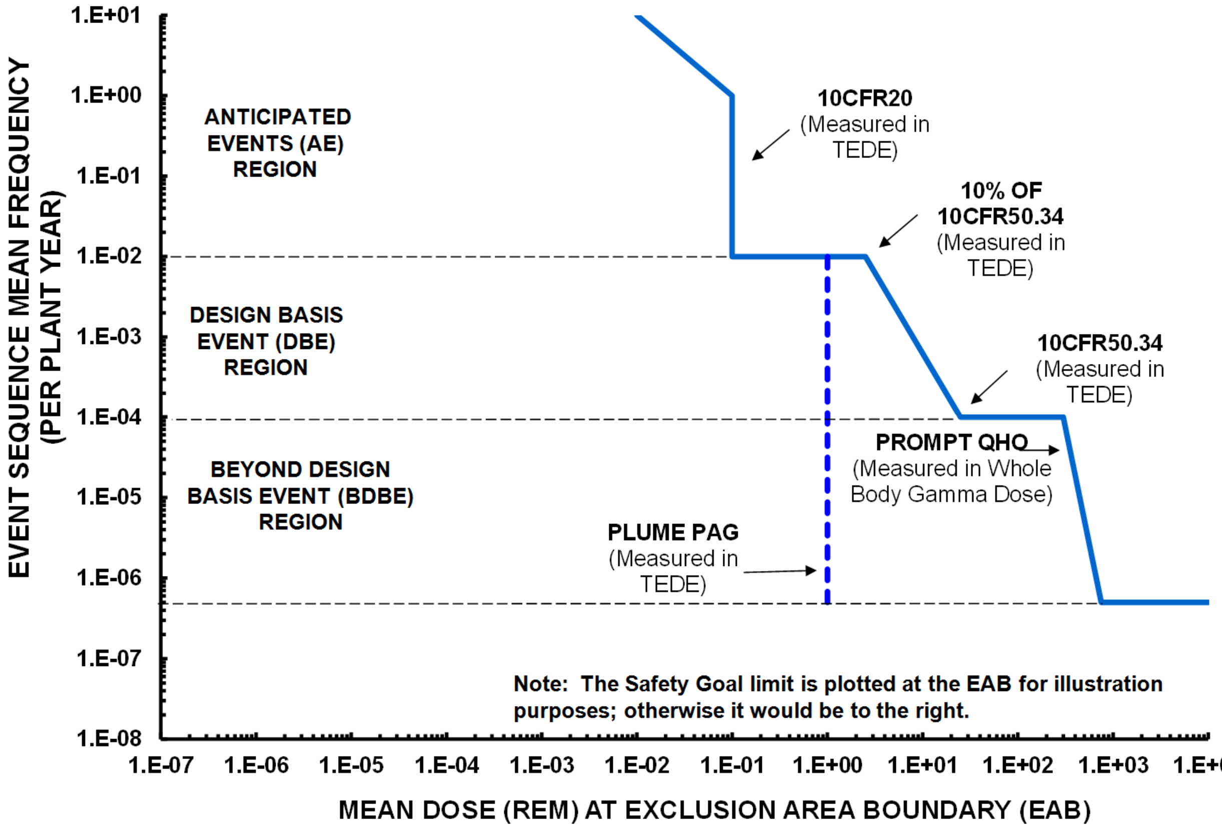


Figure 2.a.-1 NGNP Frequency-Consequence (F-C) Curve.

2.a.-2 Licensing Basis Event Selection for NGNP
• Item 2.a.-2 Establish and endorse a structured, risk-informed, performance-based approach for selecting and categorizing licensing basis events as they may occur over a broad spectrum from normal operation to rare, off-normal events. The approach should address the concept of adequate protection through an appropriate balance between defense-in-depth and risk considerations. In developing staff positions on this approach, NRC is requested to: • Establish frequency ranges based on mean event sequence frequency for the LBE event categories. <u>Summary of NGNP Position</u> Uncertainty distributions are evaluated for the mean event sequence frequency and the mean consequence for each LBE. The mean frequency is used to determine whether the event sequence family is an AE, DBE, or BDBE. If the upper or lower bound on the LBE frequency straddles two or more regions, the LBE is compared against the consequence criteria for each region. The mean, lower (5%) bound, and upper (95%) bound consequences are explicitly compared to the consequence criteria in all applicable LBE regions. The NGNP approach of utilizing the mean event sequence frequency plus uncertainty distributions is consistent with the approach presented in ANS 53.1.
Requested Updates to Assessment Reports
Section 2.1.4, starting on page 16 thru page 17 ("Acceptance Criteria for Anticipated Operational Occurrences") should be revised to reflect agreements that AEs are to be evaluated realistically using mean analyses for frequency and consequence relative to the 10 CFR 20 limit of 100 mrem.
Summary of Recent NRC Interactions
• April 16, 2012, public meeting with NRC in Rockville, MD. • May 16, 2012, public meeting with NRC in Rockville, MD. • NRC Action (May 16, 2012) to rewrite the assessment report to clarify its intent regarding AE calculations and state that Chapter 11 analyses should be performed against 10 CFR Part 20 using mean analyses.
Summary of Related Regulatory History
NUREG-1338, Section 3.2.2.1 – Accident Selection, March 1989.

Key NGNP References
• “Next Generation Nuclear Plant Licensing Basis Events Selection White Paper,” INL/EXT-10-19521, CCN 222013, September 16, 2010. • “Next Generation Nuclear Plant Probabilistic Risk Assessment White Paper,” INL/EXT-11-21270, CCN 224329, September 20, 2010. • April 16, 2012, NGNP presentation to the staff and related meeting summary. • May 16, 2012 NGNP presentation to the staff and related meeting summary. • August 22, 2012 meeting summary; the staff recognized our position to evaluate AEs realistically using mean analysis methods; the staff had no further questions on this topic.

2.a.-3 Licensing Basis Event Selection for NGNP
• Item 2.a.-3 Establish and endorse a structured, risk-informed, performance-based approach for selecting and categorizing licensing basis events as they may occur over a broad spectrum from normal operation to rare, off-normal events. The approach should address the concept of adequate protection through an appropriate balance between defense-in-depth and risk considerations. In developing staff positions on this approach, NRC is requested to: • Endorse the "per plant-year" method for addressing risk at multi-reactor module plant sites. <u>Summary of NGNP Position</u> The frequencies of LBEs are expressed in units of events per plant-year where a plant is defined as a collection of reactor modules having certain shared systems. *(LBE White Paper,* page *2)* The expression of the frequency metric on a per plant-year basis enables the risk assessment to include event sequences involving only one or multiple reactor module source terms and thereby provides a more complete risk assessment as compared with the approach of analyzing each reactor module on an independent reactor-year basis. *(LBE White Paper, page 19)*
Requested Updates to Assessment Reports
Revise the Assessment Report, page 12, to incorporate the agreement that events are categorized on a "per plant-year" basis. The frequency of LBEs is expressed on a per plant-year basis where a plant is defined as a collection of reactor modules having selected shared systems, and that the guidelines for the upper and lower frequency bounds for categorizing events be on a per plant-year basis.
Summary of Recent NRC Interactions
• Listing of public meetings and publicly noticed phone calls: • May 16, 2012, public meeting on related LBE issues at NRC in Rockville, MD. • July 10, 2012, public meeting on Risk-Informed, Performance-Based Licensing Approach issues at NRC in Rockville, MD. • August 22, 2012, publically noticed conference call requested agreements and resolutions. • Summary of previous agreements and resolutions (from Issues Spreadsheets): • August 22, 2012, public meeting, the NRC stated its agreement that events are categorized on a "per plant-year" basis rather than a "reactor-year" basis. • Summary of NRC and NGNP action items, and their status: • None. NRC staff has agreed with the NGNP approach to categorize events on a "per plant-year" basis.

Summary of Related Regulatory History
NUREG-1338, “Pre-application Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor (MHTGR),” December 1995, Section 5.2.1. NRC, “Safety Goals for the Operation of Nuclear Power Plants – Policy Statement,” August 1986. NRC, “Use of Probabilistic Risk Assessment Methods in Nuclear Regulatory Activities – Policy Statement,” August 1995. NRC, “Regulation of Advanced Reactors – Policy Statement,” October 2008. NRC, 10 CFR 52.81, “Standards for Review of Applications.” SECY-98-0300, “Options for Risk-Informed Revisions to 10 CFR Part 50 – Domestic Licensing of Production and Utilization Facilities,” December 23, 1998. The staff has proposed a high-level approach for incorporating risk-informed attributes into the Part 50 regulations, and is seeking Commission approval to proceed with a phased implementation strategy. After receiving Commission guidance, the staff will develop a rulemaking plan, which includes more complete resource and schedule estimates. Two primary objectives of this effort are to develop a risk-informed regulatory framework that will enhance safety as well as reducing unnecessary staff and licensee burden. Attachment 5 to this SECY identifies risk metrics and acceptance guidelines as an implementation issue for risk-informing Part 50. SECY-03-0047, “Policy Issues Related to Licensing Non-Light-Water Reactor Designs,” March 28, 2003. The issues covered by this paper pertain to the approach to licensing on key aspects of reactor design and operation. The SECY identifies that non-LWR reactor designs should include licensing criteria and risk metrics that are directed toward the same level of accident and core damage prevention as current criteria as well as the same level of accident mitigation. SECY-04-0157, “Status of Staff’s Proposed Regulatory Structure for New Plant Licensing and Potentially New Policy Issues,” August 30, 2004. To determine that the overall objectives of the regulatory structure have been met (e.g., enhanced effectiveness and efficiency), the staff identified key characteristics for the regulatory structure. Examples include: • Flexible—The technology-neutral and technology-specific frameworks are developed in such a manner that they allow for changes and modifications to occur, in an efficient and effective manner, that are based on new information, knowledge, etc., and can be adapted to any technology-specific reactor design; • Risk-informed—Risk information and risk insights are integrated into the decision-making process such that there is a blended approach using both probabilistic and deterministic information; • Performance-based—The guidance and criteria, when implemented, will produce a set of safety requirements that will minimize prescriptive means for achieving its goals, and therefore, will be performance oriented to the extent practical;

- Uncertainty—The guidance and criteria will include treatment of the different types of uncertainties; and
- Defense-in-depth—Defense-in-depth is maintained and is an integral part of the framework.

Key NGNP References

Supporting reports/documentation:

- “Next Generation Nuclear Plant Licensing Basis Events Selection White Paper,” INL/EXT-10-19521, CCN 222013, September 16, 2010 (ML102630246).
- NRC to NGNP letter “Next Generation Nuclear Plant – Request for Additional Information Letter No. 005 Regarding Risk-Informed, Performance-Based Licensing Approach,” August 3, 2011 (ML112140336).
- NGNP to NRC letter “Response to Nuclear Regulatory Commission Request for Additional Information Letter No. 005 Regarding the Risk-Informed, Performance-Based Licensing Approach – NRC Project #0748,” October 14, 2011 (CCN 225601) (ML11290A188).
- NRC to NGNP letter “Next Generation Nuclear Plant–Assessment of White Papers On Fuel Qualification, Mechanistic Source Terms, Defense-In-Depth Approach, Licensing Basis Event Selection, And Safety Classification of Systems, Structures, And Components,” February 15, 2012, (ML120240651), Section 2.1 of Enclosure 2 (ML120170084).
- NGNP to NRC letter, “Confirmation of Requested NRC Staff Positions – NRC Project #0748,” July 6, 2012 (CCN 227793) (ML121910310).

Applicable slides from past meetings:

- May 16, 2012, NGNP presentation at NRC public meeting on related LBE issues at NRC in Rockville, MD.
- July 10, 2012, NGNP presentation at NRC public meeting on Risk-Informed, Performance-Based Licensing Approach issues at NRC in Rockville, MD.
- August 22, 2012, NGNP presentation at NRC public telecom with NRC.

NRC and/or INL meeting summary notes:

- May 16, 2012, public meeting on related LBE issues at NRC in Rockville, MD.
- July 10, 2012, public meeting on Risk-Informed, Performance-Based Licensing Approach issues at NRC in Rockville, MD.

2.a.-4 Licensing Basis Event Selection for NGNP

Item 2.a.-4 Establish and endorse a structured, risk-informed, performance-based approach for selecting and categorizing licensing basis events as they may occur over a broad spectrum from normal operation to rare, off-normal events. The approach should address the concept of adequate protection through an appropriate balance between defense-in-depth and risk considerations. In developing staff positions on this approach, NRC is requested to:

- Agree on key terminology and naming conventions for event categories.

Summary of NGNP Position

NGNP had an action (from the May 16 and July 10 meetings) to propose an updated naming convention for the class of events previously referred to as Anticipated Operational Occurrences (AOOs), events sequences in the frequency range >1E-02 per plant-year. During the August 22 meeting, NGNP proposed to refer to this class of events as "Anticipated Events." This will distinguish this class of events from those set of LWR Anticipated Operational Occurrences required to be included within the analyses of Design Basis Accidents (Safety Analysis Report - Chapter 15 Transient and Accident Analyses).

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

- AEs, which encompass planned and anticipated events. The doses from AEs are required to meet normal operation public dose requirements. AEs are utilized to set operating limits for normal operation modes and states.
- DBEs encompass unplanned, off-normal events not expected in the plant's lifetime, but which might occur in the lifetimes of a fleet of plants. The doses from DBEs are required to meet accident public dose requirements. DBEs are the basis for the design, construction, and operation of the SSCs during accidents.
- 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.

Requested Updates to Assessment Reports

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

The following key sections from this paper should be revised to be consistent with the NGNP Position described above.

Section 2.1.4 LBE Outcome Objective 4 – Event Consequence Acceptance Limits: **Acceptance Criteria for Anticipated Operational Occurrences** should be revised to reflect the agreement that the term AEs are to be for those events in the frequency range greater than 1E-02 and are distinct from AOOs evaluated in Chapter 15.

Section 2.3.2 SSC Outcome Objective 2 – Acceptable Classification Categories: **Treatment of AOOs** should be revised to reflect the agreement that the term AEs are to be for those events in the frequency range greater than 1E-02 and are distinct from AOOs evaluated in Chapter 15.

Summary of Recent NRC Interactions
• May 16, 2012, public meeting at NRC in Rockville, MD. • July 10, 2012, public meeting at NRC in Rockville, MD. • August 22, 2012, publically noticed conference call requested agreements and resolutions. • The term "Anticipated Events" will be used to describe event sequences in the frequency range >1E-02 per plant-yr; the staff recognized our position to use the term AEs consistent with the discussion in "Mean Analysis for LBE Frequency Ranges."
Summary of Related Regulatory History
SECY-93-092, "ISSUES PERTAINING TO THE ADVANCED REACTOR (PRISM, MHTGR, AND PIUS) AND CANDU 3 DESIGNS AND THEIR RELATIONSHIP TO CURRENT REGULATORY REQUIREMENTS dated April 8, 1993, (ML040210725), Enclosure 1.A *Accident Evaluation* presented an approach wherein events would be categorized according to expected frequency of occurrence. SECY-03-0047 Issue 4 Recommendation: provides that the actual probabilistic criteria for each event category would be developed as a follow-on activity (i.e., as part of the development of a framework for future plant licensing) and would be consistent with the level of safety for future plants and that the approach would result in a set of design basis accidents for each plant design (i.e., consisting of key accident scenarios from each event category).
Key NGNP References
• "Next Generation Nuclear Plant Licensing Basis Events Selection White Paper," INL/EXT-10-19521, CCN 222013, September 16, 2010. • May 16, 2012, NGNP presentation to NRC staff and associated meeting minutes. • July 11, 2012, NGNP presentation to NRC staff and associated meeting minutes. • August 22, 2012, NGNP presentation to NRC staff.

2.a.-5 Licensing Basis Event Selection for NGNP
• Item 2.a.-5 Establish and endorse a structured, risk-informed, performance-based approach for selecting and categorizing licensing basis events as they may occur over a broad spectrum from normal operation to rare, off-normal events. The approach should address the concept of adequate protection through an appropriate balance between defense-in-depth and risk considerations. In developing staff positions on this approach, NRC is requested to: • Agree on the frequency cutoffs for the Design Basis Event (DBE) and Beyond Design Basis Event (BDBE) regions. <u>Summary of NGNP Position</u> The lower cutoff of the Design Basis Event frequency set at 1E-4 per plant-year is acceptable and is adequate to ensure meeting the QHOs. Defining Beyond Design Basis Events as those event sequences with mean frequencies less than the DBE lower cutoff and greater than 5E-7 per plant-year is acceptable and is adequate to ensure meeting the QHO for prompt fatality. Note: the PRA includes event sequences down to a screening criterion of 1E-8 per plant-year to ensure no "cliff edge sequences" occur. The NGNP cut-off frequencies for the AE, DBE, and BDBE categories are consistent with the frequencies presented in ANS 53.1.
Requested Updates to Assessment Reports
ASSESSMENT OF WHITE PAPER SUBMITTALS ON DEFENSE-IN-DEPTH, LICENSING BASIS EVENT SELECTION, AND SAFETY CLASSFICATION OF STRUCTURES, SYSTEMS AND COMPONENTS – The following key sections from this paper should be revised to be consistent with the NGNP described above. 2.1 Licensing Basis Event Selection Section 2.1.3 LBE Outcome Objective 3 – Licensing Basis Event Frequency Ranges should be revised to reflect agreements on the process of establishing the event regions (per plant year) and to note the frequency regions do not adjust with respect to the number of modules in a plant, but that the event sequence frequency would be expected to be higher in plants with multiple modules (e.g., for a 4 module plant an event sequence frequency would be expected to be ~ 4× that of a single module plant –assuming independence). Further, the Summary of Findings section should be revised to reflect agreements on the Cutoff Frequencies for the DBE and BDBE Event Sequence Categories. Section 2.1.5 LBE Outcome Objective 5 – Lower Bound of Event Frequency should be revised to reflect agreements on the establishment of the Event Sequence Boundaries.

Summary of Recent NRC Interactions
• May 16, 2012, public meeting with NRC in Rockville, MD. • July 10, 2012, public meeting with NRC in Rockville, MD. • July 24, 2012, public meeting with NRC in Rockville, MD. • September 6, 2012, public conference call. • September 19 -20, 2012, public meeting with NRC in Rockville, MD. • Summary of previous agreements and resolutions (September 19th meeting): – A frequency lower than 1E-04 coupled with the DBE Acceptance criteria (25 rem) is not required to meet the NRC QHOs. – A frequency lower than 5E-07 is not required to meet the NRC QHO irrespective of dose.
Summary of Related Regulatory History
NUREG-1338, Section 13.1.1 DOE Proposal for Reduced Emergency-Preparedness Requirements for the MHTGR, March 1989. NUREG-1338, Section 15.1 and 15.2, March 1989.
Key NGNP References
• "Next Generation Nuclear Plant Licensing Basis Events Selection White Paper," INL/EXT-10-19521, CCN 222013, September 16, 2010. • "Next Generation Nuclear Plant Probabilistic Risk Assessment White Paper," INL/EXT-11-21270, CCN 224329, September 20, 2010. • May 16, 2012, NGNP presentation to NRC and associated meeting minutes. • July 10, 2012, NGNP presentation to NRC and associated meeting minutes. • July 24, 2012, NGNP presentation to NRC and associated meeting minutes. • September 6, 2012, NGNP presentation to NRC staff and associated meeting minutes. • September 19-20, 2012, NGNP presentations to the NRC staff and associated meeting minutes.

2.a.-6 LBE Selection for NGNP - LBE Selection Process
Item 2.a.-6 Establish and endorse a structured, risk-informed, performance-based approach for selecting and categorizing licensing basis events as they may occur over a broad spectrum from normal operation to rare, off-normal events. The approach should address the concept of adequate protection through an appropriate balance between defense-in-depth and risk considerations. In developing staff positions on this approach, NRC is requested to: • Endorse the overall process for performing assessments against TLRC, including issues with uncertainties and the probabilistic risk assessment (PRA), the calculational methodologies to be employed (conservative vs. best estimate), and the adequate incorporation of deterministic elements. <u>Summary of NGNP Position</u> The overall process described for performing assessments against the TLRC including the use of engineering judgment to address uncertainties is an appropriate approach for identifying and analyzing Licensing Basis events in a Risk-Informed manner. Specific attributes of the LBE evaluation process include the use a plant specification PRA aid in the identification and evaluation of LBEs with respect to the Frequency Consequence Curve. Within this evaluation, the event sequence frequency (which includes the initiator and well as subsequent plant responses) will be used to determine the LBE frequency. Analysis of the consequences associated with event sequences will be performed using a combination of best estimate and conservative evaluations including the explicit modeling of uncertainty. Consequence analysis methods utilized will be based on the frequency categories (See Position 2.a – Placement of the TLRC on F-C Curve): • AEs , Frequency > 1E-2 per plant-year: • Consequences realistically analyzed. Performed on a cumulative annual basis for demonstrating for compliance with 10 CFR 20. • DBEs, 1E-02 < Frequency > 1E-04 per plant-year: • Consequences conservatively analyzed. Acceptance criterion is the 95% upper bound of the mean value is bound by the TLRC curve associated with the LBE frequency. Event sequences may be combined into similar families of events. • BDBEs , 1E-04 < Frequency > 5E-07 per plant-year: • Consequences realistically analyzed. Summed together with other LBEs for demonstrating compliance with respect to the NRC Safety Goals - QHOs. LBEs with frequencies, which “straddle” a frequency boundary, will be analyzed following the methodologies and acceptance criteria of both categories. Design Basis Accidents are deterministically selected from review of LBEs, by assuming that only SSCs relied on to meet 10 CFR 50.34 (those classified as safety-related) are available. Consequence acceptance criterion is the 95% upper bound of the mean value meets 10 CFR 50.34 (10 CFR 52.79) offsite dose limits. The NGNP LBE identification and evaluation process including consequence methodologies for the AE, DBE, and BDBE categories and selection of DBAs is consistent the process presented in ANS 53.1.

Requested Updates to Assessment Reports
Assessment of white paper submittals on defense-in-depth, licensing basis event selection, and safety classification of structures, systems and components. The following key sections from this paper should be revised to be consistent with the NGNP described above. 2.1 Licensing Basis Event Selection **Section 2.1.1 LBE Outcome Objective 1 – Structured Process for Licensing Basis Event Selection, Summary of Findings** Bullet 1 "Deterministic elements of the proposed approach need to be strengthened to ensure conservative selection of bounding events, including events used to justify proposed emergency response measures" should be revised to note agreements reached with respect to the process for performing the LBE assessments and, bullet 2 "There is insufficient design detail available to fully interpret or understand how events will be selected, ..."should be revised to state that review of the implementation of the process will occur during subsequent licensing activities for an applicant.
Summary of Recent NRC Interactions
• May 16, 2012, public meeting with NRC in Rockville, MD. • July 10, 2012, public meeting at NRC in Rockville, MD. • August 22, 2012, publically noticed conference call requested agreements and resolutions: • Summary of previous agreements and resolutions. • July 10, 2012, meeting: • Confirmed agreement on use of event sequences as presented in the May 16th Meeting. • Agreement on use of realistic approach for compliance for AEs, no issue with respect to DBE or BDBEs. August 22, 2012, meeting notes – Confirmed calculation methodologies for LBE events.
Summary of Related Regulatory History
NUREG-1338, Rev 0, Section 3.2.2.1 – Accident Selection. NUREG-1338, Rev 0, Section 5.2.1 – Accident Selection. SECY-03-0047, "Policy Issues Related to Licensing Non-Light-Water Reactor Designs," dated March 28, 2003, (ML030160002) Issue 4 Use an approach where probabilistic information is supplemented by deterministic engineering judgment.

Key NGNP References
• "Next Generation Nuclear Plant Licensing Basis Events Selection White Paper," INL/EXT-10-19521, CCN 222013, September 16, 2010. • "Next Generation Nuclear Plant Probabilistic Risk Assessment White Paper," INL/EXT-11-21270, CCN 224329, September 20, 2010. • May 16, 2012, NGNP presentation to NRC staff and associated meeting notes. • July 10, 2012, NGNP presentation to NRC staff and associated meeting notes. • August 22, 2012, meeting notes – confirmed calculation methodologies for LBE events.

2.a.-7 Licensing Basis Event Selection for NGNP

- Item 2.a.-7 Establish and endorse a structured, risk-informed, performance-based approach for selecting and categorizing licensing basis events as they may occur over a broad spectrum from normal operation to rare, off-normal events. The approach should address the concept of adequate protection through an appropriate balance between defense-in-depth and risk considerations. In developing staff positions on this approach, NRC is requested to:
- Endorse the proposed process and categorizations for structures, systems, and components classification.

Summary of NGNP Position
The specific objectives of the SSC Classification white paper are to seek NRC concurrence on the following:

- The NGNP approach to risk-informed safety classification and special treatment that blends the strengths of probabilistic and deterministic methods is acceptable.
- The NGNP risk-informed safety classification categories and the bases for SSC classification within each category are acceptable.
- The special treatment for the SR category of classification is commensurate with ensuring the SSCs ability to perform their required safety function for DBEs and high consequence BDBEs.
- The special treatment for the NSRST category is commensurate with ensuring the SSCs ability to perform their safety function of providing significant DID.

The risk-informed performance-based process of classifying SSCs as safety-related is to determine the required safety functions for DBEs and BDBEs:

- For DBEs, the required safety functions are those functions that need to be performed to meet the Top Level Regulatory Criteria (TLRC) associated with the DBE region.
- For BDBEs with consequences above the DBE region's dose limits of 10 CFR 50.34 (10 CFR 52.79); the required safety functions are those that need to be performed to prevent them from increasing in frequency into the DBE region where their consequences would be unacceptable.

For each required safety function, determination is made of which SSCs are available and have sufficient capability and reliability to meet the required safety function. From this review, a set of SSCs are classified as safety-related to assure that the required safety functions are accomplished, as discussed in Section 1.5.

As discussed in Section 3.4 of the NGNP SSC White Paper, SSCs are required to perform a function in response to LBEs in one or more of the regions of the frequency-consequence curve. This performance function is applicable to LBEs in which the SSC mitigates the consequences of the challenge, as well as those in which its reliability helps to reduce the LBE frequency and higher consequences LBEs.

Also, as discussed in Section 3.6.1 of the NGNP SSC White Paper, the special treatment for the safety-related SSCs is commensurate with that needed for the SSCs to achieve their capability and reliability requirements during DBEs to meet the TLRC. Capability requirements are derived from accident mitigation considerations, whereas reliability requirements are derived from accident prevention considerations. Special treatment measures for this category focus on both the capability of SSCs to mitigate DBEs and the reliability of SSCs to prevent high consequence BDBEs.
Requested Updates to Assessment Reports
NGNP believes that the revised RIPB assessment report should contain changes to certain follow up items per the summary shown in Attachment 2.a.-7.
Summary of Recent NRC Interactions
Public meetings and publicly noticed phone calls: • May 16, 2012, public meeting on related LBE issues at NRC in Rockville, MD. • July 10, 2012, public meeting on Risk-Informed, Performance-Based Licensing Approach issues at NRC in Rockville, MD. • September 6, 2012, public conference call on SSC issues. Summary of previous agreements and resolutions: • September 6, 2012, public teleconference. • In concept, the NRC is on board with NGNP's approach for SSC Safety Classification. July 10, 2012, public meeting: • The NRC acknowledged that the working group's conclusion regarding the need for an exemption request (pages 41-42 of Assessment Report) may have been "presumptuous." • NGNP noted that agreement was reached at the May 16th meeting that events NGNP classifies as AOOs (now AEs) would include transients found in Chapter 11 and should be evaluated realistically (see issue 2.a.-4). With respect to SSC Assessment Report Issue No. 12 regarding AOO (now AE) classification, the NRC agreed to delete from the assessment report (page 36) the following wording: • It is regulatory practice for LWRs that those SSCs credited with prevention and mitigation of AOOs are designated (using deterministic judgment) as SR to ensure the integrity of the principle fission product barriers (e.g., fuel barrier and RCPB barrier) rather than to ensure that the 10 CFR Part 20 limits are met. With respect to SSC issue No. 13, the NRC agreed to delete from the assessment report (page 36) the following wording: • The NRC staff stated in its review of the proposed risk-informed licensing approach for the Pebble Bed Modular Reactor (PBMR) that SSCs which are relied upon to prevent the frequency of an LBE from increasing from a lower event category (e.g., DBE) to a higher event category (e.g., AOO) should be categorized as SR. The working group believes that this previous position is also applicable to the NGNP risk-informed licensing approach. May 16, 2012, public meeting:

- NRC and NGNP reached agreement that events categorized as AOOs (now AEs) will be evaluated in FSAR Chapter 11 realistically on an expected mean basis versus the 10 CFR 20 offsite dose limit.

Summary of Related Regulatory History

NUREG-1338, *"Pre-application Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor (MHTGR),"* December 1995, Sections 4.2.5, 5.2.7, and 5.3.14.

NRC, "Safety Goals for the Operation of Nuclear Power Plants – Policy Statement," August 1986.

NRC, "Use of Probabilistic Risk Assessment Methods in Nuclear Regulatory Activities – Policy Statement," August 1995.

NRC, *"Policy Statement on the Regulation of Advanced Reactors,"* October 2008.

NRC, 10 CFR 52.81, "Standards for Review of Applications."

SECY-98-0300, "Options for Risk-Informed Revisions to 10 CFR Part 50 – Domestic Licensing of Production and Utilization Facilities," December 23, 1998.

> The staff has proposed a high level approach for incorporating risk-informed attributes into the Part 50 regulations, and is seeking Commission approval to proceed with a phased implementation strategy. After receiving Commission guidance, the staff will develop a rulemaking plan, which includes more complete resource and schedule estimates. Two primary objectives of this effort are to develop a risk-informed regulatory framework that will enhance safety as well as reducing unnecessary staff and licensee burden. To initiate this phased effort, the staff is recommending (Option 2) changes to the regulatory scope of SSCs needing special treatment in such areas as quality assurance, environmental qualification, Technical Specifications, 10 CFR 50.59 and ASME code. This will be accomplished, in part, by developing risk-informed definitions for safety-related and safety important SSCs. While this approach would allow, "grading" of special treatment requirements on SSCs based upon their risk importance, system functional capabilities would not be removed. Rather, the SSC functional capabilities (for low risk important SSCs) would remain in the plant and be expected to perform their design function but without additional margin, assurance or documentation associated with high safety significant SSCs.

SECY-03-0047, "Policy Issues Related to Licensing Non-Light-Water Reactor Designs," March 28, 2003.

> The issues covered by this paper pertain to the approach to licensing on key aspects of reactor design and operation. As part of Issue 4, the staff recommended that a probabilistic approach be allowed for the safety classification of structures, systems, and components.

SECY-04-0157, “Status of Staff’s Proposed Regulatory Structure for New Plant Licensing and Potentially New Policy Issues,” August 30, 2004.

To determine that the overall objectives of the regulatory structure have been met (e.g., enhanced effectiveness and efficiency), the staff identified key characteristics for the regulatory structure. Examples include:

- Flexible—The technology-neutral and technology-specific frameworks are developed in such a manner that they allow for changes and modifications to occur, in an efficient and effective manner, that are based on new information, knowledge, etc., and can be adapted to any technology-specific reactor design;
- Risk-informed—Risk information and risk insights are integrated into the decision-making process such that there is a blended approach using both probabilistic and deterministic information;
- Performance-based—The guidance and criteria, when implemented, will produce a set of safety requirements that will minimize prescriptive means for achieving its goals, and therefore, will be performance oriented to the extent practical;
- Uncertainty—The guidance and criteria will include treatment of the different types of uncertainties; and
- Defense-in-depth—Defense-in-depth is maintained and is an integral part of the framework.

SECY-10-0034, “Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs,” March 28, 2010.

- This SECY summarizes the NRC’s position on a number of advanced reactor policy issues including classification of SSCs for small modular reactors (SMRs) in general and to the HTGR proposed by NGNP. During its reviews of recent LWR design and license applications, the NRC staff has used deterministic judgment, complemented by insights from the design-specific PRA, to review SSCs relied on to prevent or mitigate safety-significant licensing-basis events. In conducting its review, the staff verified that safety margins were adequate to ensure the integrity and performance of safety-significant SSCs using a conservative analysis or a best-estimate analysis with consideration of uncertainties. The NRC staff expects to apply this approach to most of the advanced reactor design reviews. If necessary, special treatment requirements would be established to ensure the required performance capability and reliability of the safety-significant SSCs, using deterministic engineering judgment, complemented by insights and information from the design-specific PRA. The Department of Energy (DOE) and NRC stated that they planned to use this approach to classify the SSCs for the NGNP in the August 2008 Licensing Strategy Report to Congress.

Key NGNP References
Supporting reports/documentation: • INL/EXT-10-19509, "Next Generation Nuclear Plant Structures, Systems, and Components Safety Classification White Paper," September 21, 2010 (CCN 221997) (ML102660144). • NRC to NGNP letter "Next Generation Nuclear Plant – Request for Additional Information Letter No. 005 Regarding The Risk-Informed, Performance-Based Licensing Approach," August 3, 2011 (ML112140336). • NGNP to NRC letter "Response to Nuclear Regulatory Commission Request for Additional Information Letter No. 005 Regarding the Risk-Informed, Performance-Based Licensing Approach – NRC Project #0748," October 14, 2011 (CCN 225601) (ML11290A188). • NRC to NGNP letter "Next Generation Nuclear Plant–Assessment of White Papers On Fuel Qualification, Mechanistic Source Terms, Defense-In-Depth Approach, Licensing Basis Event Selection, And Safety Classification of Systems, Structures, And Components," February 15, 2012, (ML120240651), Section 2.3 of Enclosure 2 (ML120170084). • NGNP to NRC letter, "Confirmation of Requested NRC Staff Positions – NRC Project #0748," July 6, 2012 (CCN 227793) (ML121910310). Applicable slides from past meetings: • NGNP RIPB White Papers Issues Presentation Slides, May 16, 2012. • NGNP SSC White Paper Issues Presentation Slides, July 10, 2012. • NGNP SSC White Paper Issues Presentation Slides, September 6, 2012. NRC and/or INL meeting summary notes: • NGNP Notes, May 16, 2012, NRC Public Meeting, "RIPB Licensing Approach." • Memo from Amy Cubbage (NRC NRO), "Summary of May 16, 2012 Public Meeting on Next Generation Nuclear Plant Risk-Informed, Performance-Based Licensing Approach," June 12, 2012 (ML12160A188). • NGNP Notes, July 10 NRC Public Meeting, "Risk-Informed, Performance-Based Licensing Approach," July 26, 2012.

Attachment 2.a-7-1
NRC SSC Assessment Report
Follow Up Items with Requested NRC Updates

10 CFR 50.2 - Issue SSC-03:

- The NGNP criteria for determining SR SSCs should be stated in a fashion similar to 10 CFR 50.2 and should be equivalent, in principle, to this definition. In addition, design basis events in this definition should include AEs.

NGNP Response:

- At the July 10, 2012, NGNP presented the technology-specific required safety functions that are at a comparable level to those in the LWR-specific 10 CFR 50.2.
- As noted during the May 16, 2012, LBE meeting, NGNP AEs relate to plant transients found in FSAR Chapters 11/12 and will be evaluated realistically on an expected mean basis versus the 10 CFR 20 offsite dose limit; the Staff agreed with this approach during the May 16th meeting.

Requested NRC Action:
Revise the Assessment Report language to clarify that SSCs that control consequences for AEs (or keep high consequence DBEs from increasing in frequency) are not assumed to be safety-related.

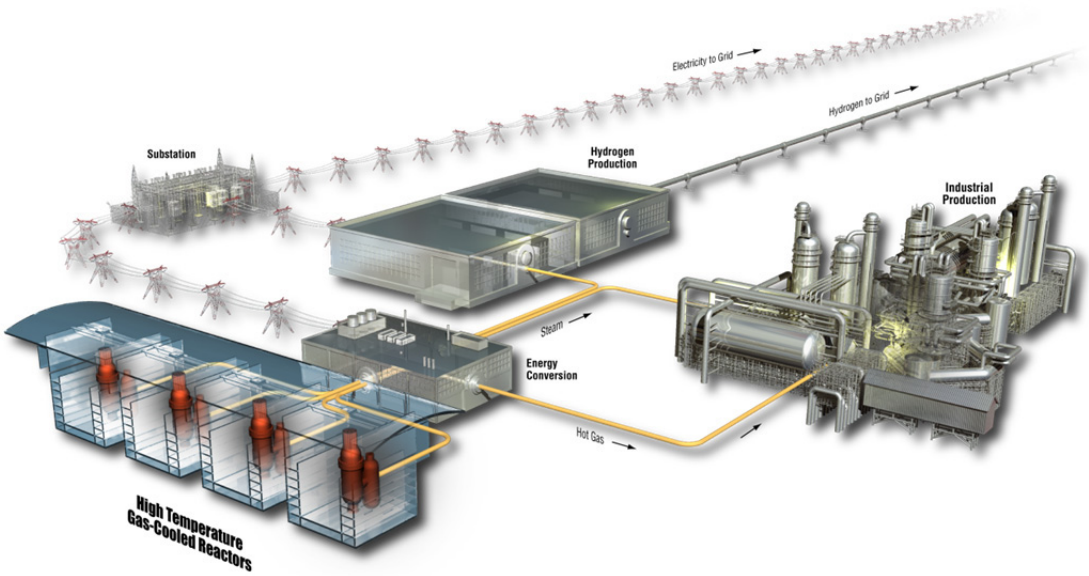
Defense-in-Depth - Issues SSC-04, 13, and 12

- NGNP's specification of treatment for select non-safety related SSCs as a means of incorporating defense-in-depth is incomplete (see sections 2.3.2 and 2.3.4)
- NGNP Response:
- Defense-in-depth is discussed, from plant capability, programmatic, and risk-informed evaluation perspectives in the NGNP white paper on Defense-In-Depth, INL/EXT-09-17139 (ML093480191).
- NGNP presented the process for the classification of SSCs in the categories of safety-related (SR), non-safety related with special treatment (NSRST), and non-safety related (NSR).
- It was noted during discussion that the SSC assessment report section made reference to a 2002 Exelon/PBMR preliminary findings letter that (incorrectly) expanded a point being made about SSCs that address beyond design-basis events to all three regions of the F-C curve. This would result in all SSCs that have safety functions to control consequences and/or event frequencies to be classified as safety-related, regardless of the LBE category.
- SSCs relied upon to prevent the frequency of DBEs with consequences greater than Part 20 offsite dose limits from increasing from a lower event category to a higher event category should be classified as safety-related. If the degree of special treatment for an SSC is to be commensurate with its safety significance, it is inappropriate that a lesser degree of special treatment be assigned to an SSC mitigating such an AE.

- In accordance with 50.49(b), SSCs involved in the prevention and mitigation of AEs should be safety-related and not classified as NSRST. Operational SSCs included in this category for mitigation of AEs are anticipated to include operational core cooling systems and operational waste treatment systems. Such SSCs credited with prevention and mitigation of AEs are designated (using deterministic judgment) as safety-related to ensure the integrity of the principle fission product barriers rather than to ensure that Part 20 limits are met. The NRC considers AE dose acceptance criteria to be a potential policy issue.

  Requested NRC Action:
  Revise the assessment report language to remove reference to the 2002 Exelon/PBMR letter.

Next Generation Nuclear Plant Issue Resolution Worksheet Items 3.a, 3.b, and 3.c



3.a. Establish Mechanistic Source Terms for NGNP
Item 3.a. Endorse the proposed NGNP mechanistic source terms definition - the quantities of radionuclides released from the reactor building to the environment during the spectrum of LBEs, including timing, physical and chemical forms, and thermal energy of the release. <u>Summary of NGNP Position</u> The NRC working group report accepted the definition of mechanistic source terms as reasonable with qualifications: In summary, the working group's view is that the Project's definition of event-specific mechanistic source terms for the HTGR is generally consistent with the traditional staff definitions. However, the working group believes that appropriate consideration should be given to all available barriers in the assessment of event-specific mechanistic source terms. This is a follow-up item. The outcome of fuel performance testing (both in-pile and out-of-pile) in the NGNP/AGR Fuel Program should provide additional insights in this regard. (Page 28, "Assessment of White Paper Submittals on Fuel Qualification and Mechanistic Source Terms," February 15, 2012.) NGNP believes that discussions with the staff that have occurred since issuance of the assessment report have made it clear that appropriate consideration is given to all available barriers in the assessment of event-specific mechanistic source terms.
Requested Updates to Assessment Reports
Based on discussions of follow up items to date, NGNP requests that NRC consider an update in the revised assessment report that to provides an acceptance of the definition of mechanistic source terms that is less qualified, and reflects the understanding that all available barriers are considered in the assessment of event-specific mechanistic source terms. For consistency, any updates to the definition should also be reflected in other documents being prepared by the staff to summarize the NGNP/NRC pre-licensing interactions.
Summary of Recent NRC Interactions
• Selected FQ/MST follow up items were discussed in an NRC public meeting on April 17, 2012. • Additional selected FQ/MST follow up items were discussed in an NRC public meeting on July 24, 2012. • FQ/MST follow up items were also discussed in an NRC public meeting on September 20, 2012. • Summaries of notes, agreements, and actions resulting from the discussions of individual follow up items through September 20, 2012, are included in the FQ/MST items EXCEL spreadsheet.

Summary of Related Regulatory History
NUREG-1338, “Draft Preapplication Safety Evaluation Report for the Modular High Temperature Gas-Cooled Reactor,” March 1989, pages 15-21 through 15-23. NUREG-1338, “Preapplication Safety Evaluation Report for the Modular High Temperature Gas-Cooled Reactor (MHTGR),” December 1995, pages 4-8 through 4-11. SECY-93-092, 1993, “Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and Process Inherent Ultimately Safe [PIUS]) and CANDU 3 Designs and Their Relationship to Current Regulatory Requirements,” U.S. Nuclear Regulatory Commission, April 8, 1993. SECY-03-0047, 2003, “Policy Issues Related to Licensing Non-Light- Water Reactor Designs,” U.S. Nuclear Regulatory Commission, March 28, 2003, Issue 5. SECY-05-0006, 2005 “Second Status Paper on the Staff’s Proposed Regulatory Structure for New Plant Licensing and Update on Policy Issues Related to New Plant Licensing,” January 7, 2005, Issue 6.
Key NGNP References
“Mechanistic Source Terms White Paper,” INL/EXT-10-17997, Rev. 0, Idaho National Laboratory, CCN 221271, July 21, 2010. “Response to Nuclear Regulatory Commission Request for Additional Information Letter No. 002 Regarding Next Generation Nuclear Plant Fuel Qualification and Mechanistic Source Terms,” CCN 224915, August 10, 2011. “Response to Nuclear Regulatory Commission Request for Additional Information Letter No. 003 Regarding Next Generation Nuclear Plant Fuel Qualification and Mechanistic Source Terms,” CCN 225363, September 21, 2011. FQ/MST Follow Up Items Spreadsheet Following July 24, 2012 NRC Meeting.

3.b. Establish Mechanistic Source Terms for NGNP
Item 3.b. Agree that NGNP source terms are event specific and determined mechanistically using models of radionuclide generation and transport that account for fuel and reactor design characteristics, passive features, and the radionuclide release barriers. Summary of NGNP Position NRC accepted this approach as reasonable, subject to resolution of several detailed technical follow up items as the AGR Program and the NGNP design effort continue. These items are reflected in the FQ/MST follow up items EXCEL spreadsheet, which has been updated to reflect the results of discussions through the NGNP/NRC FQ/MST meeting of July 24, 2012. Progress toward closure has been made several of the follow up items, and NGNP believes that some items can be closed at this time. See Attachment 3.b. The NRC assessment report states: "The NRC working group's overall assessment is that the proposed high-level approaches to NGNP fuel qualification and mechanistic source terms are generally reasonable, albeit with several potentially significant caveats. This means that, subject to further consideration and resolution of details and issues noted subsequently in this assessment document, the working group's review of these white papers has found no fundamental shortcomings that would necessarily preclude successful implementation of the presented high-level approaches towards establishing the technical bases for related NGNP prototype licensing submittals." (Page 5, "Assessment of White Paper Submittals on Fuel Qualification and Mechanistic Source Terms," February 15, 2012.)
Requested Updates to Assessment Reports
Based on discussions of follow up items to date, NGNP believes that the revised assessment reports should contain changes to certain follow up items per the summary shown in Attachment 3.b. NGNP requests that the revised assessment reports reconfirm the acceptability of the approach to and use of mechanistic source terms with fewer qualifications. The acceptance of the approach and use of mechanistic source terms should also be reflected in other documents being prepared by the staff to summarize the NGNP/NRC pre-licensing interactions.
Summary of Recent NRC Interactions
• Selected FQ/MST follow up items were discussed in an NRC public meeting on April 17, 2012. • Additional selected FQ/MST follow up items were discussed in an NRC public meeting on July 24, 2012. • Further dialogue on this topic was held during the NRC public meeting on siting source terms on September 20, 2012. • Summaries of notes, agreements, and actions resulting from the discussions of individual follow up items through September 20, 2012, are included in the FQ/MST items EXCEL spreadsheet.

Summary of Related Regulatory History
NUREG-1338, "Draft Preapplication Safety Evaluation Report for the Modular High Temperature Gas-Cooled Reactor," March 1989, pages 15-21 through 15-23. NUREG-1338, "Preapplication Safety Evaluation Report for the Modular High Temperature Gas-Cooled Reactor (MHTGR)," December 1995, pages 4-8 through 4-11. SECY-93-092, 1993, "Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and Process Inherent Ultimately Safe [PIUS]) and CANDU 3 Designs and Their Relationship to Current Regulatory Requirements," U.S. Nuclear Regulatory Commission, April 8, 1993. SECY-03-0047, 2003, "Policy Issues Related to Licensing Non-Light- Water Reactor Designs," U.S. Nuclear Regulatory Commission, March 28, 2003, Issue 5. SECY-05-0006, 2005 "Second Status Paper on the Staff's Proposed Regulatory Structure for New Plant Licensing and Update on Policy Issues Related to New Plant Licensing," January 7, 2005, Issue 6.
Key NGNP References
"Mechanistic Source Terms White Paper," INL/EXT-10-17997, Rev. 0, Idaho National Laboratory, CCN 221271, July 21, 2010. "Response to Nuclear Regulatory Commission Request for Additional Information Letter No. 002 Regarding Next Generation Nuclear Plant Fuel Qualification and Mechanistic Source Terms," CCN 224915, August 10, 2011. "Response to Nuclear Regulatory Commission Request for Additional Information Letter No. 003 Regarding Next Generation Nuclear Plant Fuel Qualification and Mechanistic Source Terms," CCN 225363, September 21, 2011. FQ/MST Follow Up Items Spreadsheet Following September 20, 2012, NRC Meeting.

3.c. Establish Mechanistic Source Terms for NGNP

Item 3.c. Agree that NGNP has adequately identified the key HTGR fission product transport phenomena and has established acceptable plans for evaluating and characterizing those phenomena and associated uncertainties.

Summary of NGNP Position
In its assessment report, NRC identified a number of detailed follow up items to be resolved as the AGR program continues. No demonstrable gaps in the transport phenomena or in the elements of the AGR Program related to fission product transport characterization have been identified. Therefore, NGNP would conclude that it has adequately identified the key HTGR fission product transport phenomena and has established acceptable plans for evaluating and characterizing those phenomena and associated uncertainties.

Requested Updates to Assessment Reports

Based on discussions of follow up items to date, NGNP requests that the revised assessment reports contain changes to certain follow up items per the summary shown in Attachment 3.c.

Summary of Recent NRC Interactions

- Selected FQ/MST follow up items were discussed in an NRC public meeting on April 17, 2012.
- Additional selected FQ/MST follow up items were discussed in an NRC public meeting on July 24, 2012.
- Further dialogue on the topic, specifically on follow up item FQ/MST-19, is planned for the NRC public meeting on siting source terms scheduled for September 20, 2012.
- Summaries of notes, agreements, and actions resulting from the discussions of individual follow up items through July 24, 2012, are included in the FQ/MST items EXCEL spreadsheet.

Summary of Related Regulatory History

NUREG-1338, “Draft Preapplication Safety Evaluation Report for the Modular High Temperature Gas-Cooled Reactor,” March 1989, pages 15-21 through 15-23.

NUREG-1338, “Preapplication Safety Evaluation Report for the Modular High Temperature Gas-Cooled Reactor (MHTGR),” December 1995, pages 4-8 through 4-11.

SECY-93-092, 1993, “Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and Process Inherent Ultimately Safe [PIUS]) and CANDU 3 Designs and Their Relationship to Current Regulatory Requirements,” U.S. Nuclear Regulatory Commission, April 8, 1993.

SECY-03-0047, 2003, “Policy Issues Related to Licensing Non-Light- Water Reactor Designs,” U.S. Nuclear Regulatory Commission, March 28, 2003, Issue 5.

SECY-05-0006, 2005 “Second Status Paper on the Staff’s Proposed Regulatory Structure for New Plant Licensing and Update on Policy Issues Related to New Plant Licensing,” January 7, 2005, Issue 6.

Key NGNP References

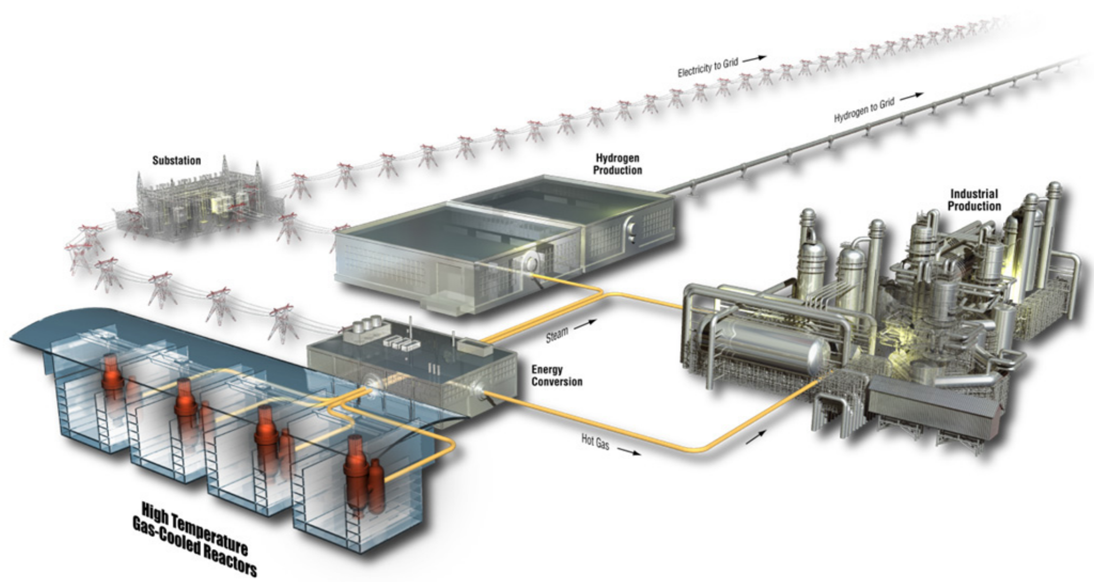
“Mechanistic Source Terms White Paper,” INL/EXT-10-17997, Rev. 0, Idaho National Laboratory, CCN 221271, July 21, 2010.

“Response to Nuclear Regulatory Commission Request for Additional Information Letter No. 002 Regarding Next Generation Nuclear Plant Fuel Qualification and Mechanistic Source Terms,” CCN 224915, August 10, 2011.

“Response to Nuclear Regulatory Commission Request for Additional Information Letter No. 003 Regarding Next Generation Nuclear Plant Fuel Qualification and Mechanistic Source Terms,” CCN 225363, September 21, 2011.

FQ/MST Follow Up Items Spreadsheet Following September 20, 2012, NRC Meeting.

Next Generation Nuclear Plant Issue Resolution Worksheet Items 4.a., 4.b., and 4.c.



4.a. Development of an Emergency Planning and EPZ Distances for NGNP – EPZ Sizing

Item 4. Develop a technology-neutral, dose-based EP framework that takes into account the modular HTGR design and its co-location with industrial processes to determine the appropriate size of the EPZ considering the proposals contained in the NGNP white paper [Letter, NGNP to NRC, October 28, 2010, "Contract No. DE-AC07-0SIDI4S17 - *Next Generation Nuclear Plant Project - Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR* - NRC Project #0748," (ADAMS Accession MLI030S0268)]. Specifically, NGNP requests that the NRC:

- Propose a new policy or revised regulations for how the emergency planning zone sizing can be scaled to be commensurate with the accident source term, fission product release, and associated dose characteristics. Key issues include:
- Using NGNP's proposed risk-informed, performance-based approach to calculate the frequency of exceeding Protective Action Guideline (PAG) values as a function of distance from the plant for a spectrum of accidents.
- Establishing criteria for determining the point at which the frequency of exceeding the PAG values is acceptably low.

<u>Summary of NGNP Position</u>

NGNP intends to implement a risk informed performance approach based in the design and licensing processes. Within this approach, and consistent with the application of the frequency-consequence curve discussed with the NRC staff, there is no licensing basis event (LBE) sequence with a frequency greater than 5×10^{-7} per plant year resulting in large offsite radiological releases that warrants the need for large emergency planning zones and extensive offsite response plans. Hence, it is justifiable and desirable to appropriately size the plume and ingestion pathway EPZs and potentially simplify emergency planning requirements for modular HTGRs. 10 CFR 50.47(c)(2) permits the size of the EPZ to be determined on a case-by-case basis for gas-cooled nuclear reactors. For HTGRs, the EPZ size 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. The methodology proposed for NGNP EPZ sizing will entail the following:

- Identify the applicable source terms:
- Determine the DBE and BDBE sequences with dose consequences
- Determine the radionuclide release source terms for each event and the time from the start of the accident to the time when a radiological release begins (consistent NGNP's proposed mechanistic source term approach) using mean values (note that using mean values is consistent with the staff's position in SECY-05-0006, Issue 6)
- Evaluate offsite dose consequences for each event and determine the distance at which the 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 Design Basis Threat scenario.

Requested Updates to Assessment Reports
None
Summary of Recent NRC Interactions
• NGNP white paper "Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR," INL/MIS-10-19799, submitted October 2010. • Public meeting with the NRC staff on January 26, 2011. • Public meeting with the NRC staff on November 14, 2012.
Summary of Related Regulatory History
• 10 CFR 50.33(g): • "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." • 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." Issue 6: Use of Scenario-Specific Source Terms for Licensing Decisions. • (p10) "In the framework, the staff used a flexible, performance-based approach to establish scenario specific licensing source terms. The key features of this approach are as follows: • Source terms for emergency preparedness should be mean values based on best-estimate calculations." • SECY-11-0152, "Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors." • (p4) "The staff considers it appropriate to be open to applicant requests for establishing SMR technology-neutral, variable distance, plume exposure EPZs." • (p4) "EP programs for SMR sites should address implications of a smaller source term and passive design features associated with SMRs. One approach could be to have the offsite EP requirements scaled to be commensurate with the SMR accident source term, fission product release, and associated dose characteristics, which are all a function of the licensed reactor power level. These factors are technology neutral, based on offsite dose, and use the EPA PAG values as the principal basis to establish standard EPZ distances. Under such an approach, different EPZ boundaries can be established for different dose limits." • (p7) "The staff intends to continue developing a technology-neutral, dose-based, consequence-oriented EP framework for SMR sites that takes into account the various designs, modularity and collocation, as well as the size of the EPZ." • EPA-400-R-92-001, "Manual of Protective Action Guides for Nuclear Incidents."

• (p2-2) “For example, the choice of EPZs for commercial nuclear power facilities has been based, primarily, on consideration of the area needed to assure an adequate planning basis for local response functions and 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.”
Key NGNP References
• NGNP white paper “Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR,” INL/MIS-10-19799, submitted October 2010 (ML0103050268). • NGNP slides from the “Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR” presentation, January 26, 2011, public meeting between NGNP and the NRC (ML110390622). • NGNP slides from the “Emergency Planning Event Selection” presentation, November 14, 2012, public meeting between NGNP and the NRC.

4.b. Development of an Emergency Planning and EPZ Distances for NGNP – Graded Emergency Planning Requirements
Item 4.b. Establish guidance for how specific emergency planning requirements in 10 CFR 50 can be applied with a graded approach, when compared to current emergency plans for L WRs, that allows for site and off site emergency plans to be developed commensurate with the NGNP design and a plume exposure EPZ at a distance from the plant for which the PAG values are demonstrated to be met (e.g., approximately 400 meters from the reactor centerline). <u>Summary of NGNP Position</u> The safety design and operating characteristics of the modular 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 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. 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. This approach would support, for example: • Simplification of onsite and offsite emergency response organization • Potential reduction of on-shift staffing requirements • Offsite fire/rescue and medical facility capabilities consistent with existing industrial hazard plans (with the addition of a nuclear/radiological incident annex if needed) • Potential reduction in number of participating agencies and jurisdictions • Potential reduction in the need for prompt notification • Consolidation and simplification of emergency response facilities • Simplification of training, exercise, and drill requirements • Offsite response and protective action strategy commensurate with the risk and potential impact of a radiological release, potentially allowing offsite emergency response to be accommodated through existing all-hazards plans that would be supplemented by a Nuclear/Radiological Incident Annex if one does not already exist for another radiological hazard. 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. No changes to these regulations are expected to be necessary for NGNP. However, implementation guidance that addresses the graded approach described above for HTGRs should be incorporated into either a stand-alone NRC guidance document or an appendix to the current industry guidance document NUREG-0654/FEMA-REP-1, “Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants.” Changes to NRC regulations are not expected to be

needed to adopt the graded approach described above.

Requested Updates to Assessment Reports
None
Summary of Recent NRC Interactions
• NGNP white paper "Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR," INL/MIS-10-19799, submitted October 2010. • Public meeting with NRC staff on January 26, 2011.
Summary of Related Regulatory History
• SECY 10-0034, "Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs," Section 4.7 Offsite Emergency Planning Requirements for SMRs • (p18) "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." • SECY-11-0152, "Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors."
• (p5) "Specific EP requirements would be commensurate with the size of the EPZ. Although the size of the EPZ would be based on offsite dose, specific EP requirements would consider such factors as event transient time and source term. For example, while the offsite dose may require a 2-mile EPZ, the timeline for this event leading to an offsite dose may be in excess of several hours. In addition, the current requirement for a licensee to notify responsible State and local governmental agencies within 15 minutes after declaring an emergency may need to be reexamined to be commensurate with the event transient time." • (p6) "A scalable EPZ scheme would allow for regulatory predictability for SMR applicants and for State and local officials. This approach would ensure the consistent application of NRC regulations and requirements in the review of EP plans prepared for SMRs. This approach is consistent with current EP requirements and would not result in a reduction in the protection of public health and safety." • EPA-400-R-92-001, "Manual of Protective Action Guides for Nuclear Incidents." • (p2-2) "For example, the choice of EPZs for commercial nuclear power facilities has been based, primarily, on consideration of the area needed to assure an adequate planning basis for local response functions and 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."

Key NGNP References
• NGNP white paper “Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR,” INL/MIS-10-19799, submitted October 2010 (ML0103050268). • NGNP slides from the “Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR” presentation, January 26, 2011, public meeting between NGNP and the NRC (ML110390622).

4.c. Development of an Emergency Planning and EPZ Distances for NGNP – Co-location with Industrial Facilities
Item 4.c. Propose guidance regarding how issues related to modularity of the designs and the co-location of multi-module plants near industrial facilities should be considered in EP planning. Summary of NGNP Position • Factors related to modularity of the designs and the co-location of multi-module plants near industrial facilities should be considered in EPZ sizing and EP planning requirements. For example: • Co-location at an existing nuclear power plant – the size of the EPZ would be influenced by the EPZ requirements for the other existing nuclear power plant. • Co-location of multiple HTGR plants 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 within an industrial facility – EP requirements would be influenced by regulatory requirements and existing emergency programs for the industrial facility. HTGRs will comply with 10 CFR 100.21(e), which requires that 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.
Requested Updates to Assessment Reports
None
Summary of Recent NRC Interactions
• NGNP white paper “Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR,” INL/MIS-10-19799, submitted October 2010. • Public meeting with NRC staff on January 26, 2011.
Summary of Related Regulatory History
• SECY-11-0152, “Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors.” • (p7) “The staff intends to continue developing a technology-neutral, dose-based, consequence-oriented EP framework for SMR sites that takes into account the various designs, modularity and collocation, as well as the size of the EPZ.”
Key NGNP References
• NGNP white paper “Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR,” INL/MIS-10-19799, submitted October

2010 (ML0103050268).

- NGNP slides from the “Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR” presentation, January 26, 2011, public meeting between NGNP and the NRC (ML110390622).