Contributing activities within the U.S. Nuclear Regulatory Commission's (NRC's) implementation action plan for improving its regulatory readiness for non-light water reactor (non-LWR) designs includes developing guidance for a flexible non-LWR regulatory review process (Strategy 3) and identifying and resolving policy issues (Strategy 5). An issue identified during interactions with stakeholders is defining appropriate performance criteria for the design features serving to retain radionuclides within facilities over a range of possible events. This draft paper has been prepared and is being released to support ongoing public discussions. This draft paper has not been subject to NRC management and legal reviews and approvals, and its contents should not be interpreted as official agency positions. Following the public discussions (including a public meeting scheduled for February 1, 2018), the staff plans to continue working on this paper as well as other activities defined in the agency's vision and strategies document. This paper and related interactions with stakeholders will be considered in a paper the staff plans to discuss with the Advisory Committee on Reactor Safeguards and subsequently provide to the Commission in early 2018.

SUBJECT: FUNCTIONAL CONTAINMENT PERFORMANCE CRITERIA FOR NON-LIGHT WATER REACTOR DESIGNS

PURPOSE:

The purpose of this paper is to seek Commission approval of the staff's recommendation to adopt a technology-inclusive, risk-informed, performance-based approach to establishing performance criteria for structures, systems, and components and corresponding programs to limit the release of radioactive materials from non-LWR designs. The staff has determined that Commission direction would be beneficial at this time to support development and possible deployment of advanced reactor technologies.

BACKGROUND:

One of the fundamental safety functions to be addressed for any nuclear reactor is limiting the release of radioactive materials from the facility. The need for the containment structures to retain radioactive materials following a break of a pipe with high-energy fluid led to the development of the pressure retaining (large dry) and pressure-suppression containment designs used for LWRs. Non-LWR technologies have operating conditions, coolants, and fuel forms that are different from LWRs. These differences may allow or possibly require different approaches to fulfilling the safety function of limiting the release of radioactive materials. The possible differences in plant designs and reliance on plant features other than a containment structure to limit the release radionuclides for some events has led to describing a "functional containment" as a barrier, or set of barriers taken together, that effectively limit the physical transport and release of radionuclides to the environment.

As described in more detail in Enclosure 1, the NRC has engaged in several pre-licensing interactions and developed policies and guidance to support the potential licensing of advanced reactor facilities. The NRC's Policy Statement on the Regulation of Advanced Reactors was first issued on July 8, 1986 (51 FR 24643) with an objective to provide all interested parties, including the public, with the Commission's views concerning the desired characteristics of advanced reactor designs. The most recent revision to the Policy Statement on the Regulation of Advanced Reactors was issued in 2008 (73 FR 60612).

The NRC interacted with the Department of Energy (DOE) and reactor developers in the late 1980s and early 1990s regarding the potential licensing of non-LWR designs. These activities resulted in the publication of assessments such as NUREG-1368, “Preapplication Safety Evaluation Report for the Power Reactor Innovative Small Module (PRISM) Liquid-Metal Reactor,” and NUREG-1338, “Draft Preapplication Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor.” The NRC staff identified a number of potential policy issues during the assessments of advanced reactor designs. The staff included a proposal for performance criteria for containments in SECY-93-092, “Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, AND PIUS) and CANDU 3 Designs and Their Relationship to Current Regulatory Requirements” (ADAMS Accession No. ML040210725). The Commission approved the staff’s proposed approach for considering containment functional performance during the pre-application interactions in the Staff Requirements Memorandum (SRM) dated July 30, 1993 (ADAMS Accession No. ML003760774). Policy issues related to non-LWRs were again brought to the Commission’s attention in SECY-03-0047, “Policy Issues Related to Licensing Non-Light Water Reactor Designs” (ADAMS Accession No. ML030160002). The containment-related issue centered on the question of under what conditions can a plant be licensed without a pressure retaining containment building (i.e., a confinement building instead of a containment). In the SRM for SECY-03-0047 dated June 26, 2003, (ADAMS Accession No. ML031770124), the Commission found it premature to decide on the best options to resolve the issue and directed the staff to pursue the development of functional performance standards and then submit options and recommendations to the Commission on this important policy decision.

The staff updated the Commission 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,” on the development of a technology neutral framework and possible approaches to resolve policy issues remaining from SECY-03-0047. SECY-05-0006 noted that there was no consensus among stakeholders on a single descriptive term such as “containment,” “confinement,” “vented low-pressure containment,” “reactor building” or “containment structure.” The paper identified technology-neutral functions and possible technology-neutral performance requirements and criteria for the combinations of civil structures and systems serving the containment function. As a follow-up to SECY-05-006, the NRC addressed the concept of functional containment and related advanced reactor issues, such as ensuring sufficient defense in depth, in an advanced notice of proposed rulemaking (ANPR) published on May 4, 2006 (71 FR 26267). In SECY-07-0101, “Staff Recommendations Regarding a Risk-Informed and Performance-Based Revision to 10 CFR Part 50,” dated June 14, 2007 (ADAMS Package Accession No. ML070790253), the NRC staff requested that the Commission defer the rulemaking activity until after the development of the licensing strategy for the Next Generation Nuclear Plant (NGNP) or receipt of an application for design certification or a license for the Pebble Bed Modular Reactor. In the SRM for SECY-07-0101 (ADAMS Accession No. ML072530501), the Commission approved the NRC staff's recommendation to defer the rulemaking activity. As described in SECY-16-0021, Discontinuation of Rulemaking Activities,” (ADAMS Accession No. ML15336A324) and the related SRM dated May 19, 2016 (ADAMS Accession No. ML16141A044), subsequent changes to the NGNP project ultimately led to the rulemaking activities being discontinued.

Although the NRC did not pursue a rulemaking as envisioned in SECY-05-0006 and subsequent ANPR, the staff continued interactions with stakeholders on policy issues related to advanced reactors. These interactions centered on the NGNP project and a series of white papers intended to help resolve key licensing issues, including functional containment performance criteria. Following interactions with DOE, Idaho National Laboratory (INL), and the Advisory Committee on Reactor Safeguards (ACRS), the NRC staff provided feedback on the white papers to DOE's Office of Nuclear Energy In a letter dated July 17, 2014 (ADAMS Accession No. ML14174A734). In July 2013, DOE and the NRC established a joint initiative to address how the general design criteria (GDC) in Appendix A, "General Design Criteria for Nuclear Power Plants," of Title 10 of the *Code of Federal Regulations*, Part 50 "Domestic Licensing of Production and Utilization Facilities" (10 CFR Part 50) may be adapted for non-LWR designs. The staff dispositioned the public comments on draft guidance and other interactions with stakeholders and issued *Regulatory Guide (RG) 1.232,* "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors" in *MONTH 2018.* The staff discusses concepts in the RG, such as a technology-inclusive approach to functional containments, that may involve policy issues requiring NRC Commission review and approval. Stakeholders identified the resolution of remaining issues related to functional containment performance criteria as an important item to enable developers to make critical design and licensing decisions.

DISCUSSION:

The staff described efforts to prepare for possible licensing of non-light water reactor (non-LWR) technologies in "NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness," (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16356A670). The staff developed implementation action plans (IAPs) to identify specific activities that the NRC will conduct in the near-term, mid-term, and long-term timeframes (ADAMS Accession Nos. ML17165A069 and ML17164A173). The IAPs included the following strategies to meet the objective of achieving regulatory readiness:

Strategy 3: Develop guidance for a flexible non-LWR regulatory review process within the bounds of existing regulations, including the use of conceptual design reviews and staged-review processes

Strategy 5: Identify and resolve technology-inclusive policy issues that impact the regulatory reviews, siting, permitting, and/or licensing of non-LWR nuclear power plants (NPPs)

The staff is currently interacting with advanced reactor stakeholders regarding a variety of policy and regulatory process issues identified in the IAPs. Examples include interactions with DOE, designers, and other stakeholders in developing approaches to identify and address plant internal events and external events, exploring possible alternatives to current security requirements, assessing siting-related guidance, and developing a proposed rule with alternative requirements for emergency planning zones. The interrelationships between these activities and with the associated performance criteria for design features such as functional containments require an integrated approach to resolving issues and developing a regulatory framework for non-LWRs.

A process for defining functional containment performance criteria in a manner that is technology inclusive, risk informed, and performance based is described in Enclosure 2. This paper defines a general structure of a technology-inclusive framework from which logical performance criteria are derived for specific design features. The basic framework is built around the identification and categorization of licensing-basis events. Like the system that has evolved for operating reactors, event categories are developed considering factors such as estimated frequencies. For each event category, performance criteria would define specific functions to be performed by a structure, system, or component (SSC) of a facility in regard to limiting the release of radionuclides. The design of each SSC would be determined based on the aggregation of performance requirements for each event category and the fundamental safety function (radionuclide retention in current discussion) as well as other potential roles that a designer may choose for that SSC. Establishing performance requirements for a set of event categories that extend from benign to severe supports the NRC philosophy of ensuring defense in depth and also generally aligns with international standards and practices. In the case of a building surrounding a reactor system, potential uses other than radionuclide retention for such a structure include providing support to cooling systems and protecting reactor systems from external events.

The staff acknowledges that the above discussion establishes more of a performance-based methodology than a definitive or prescriptive set of performance criteria for "functional containment" or other design features. In addition, the staff is continuing interactions with stakeholders to reach agreement on several technical issues such as lower bounds for event frequencies and some details fuel design limits for non-LWR technologies. However, the NRC staff and non-LWR developers need to establish a logical path forward to complete the strategies in the IAPs for a flexible licensing framework and resolve interrelated policy issues such as establishing functional containment performance criteria. The need for an integrated and consistent approach to address both prevention barriers and mitigation barriers is especially important to developers needing to make key design decisions. The design decisions require an ability to assess tradeoffs between possible costs for various design features as well as possible operating and maintenance costs for prevention and mitigation barrier alternatives. Commission approval at this time of the general overall framework, as it relates to "functional containment" performance criteria, would allow the staff and stakeholders to continue interactions and resolve other technical and policy issues. The description of a performance-based methodology is appropriate given the variety of technologies and designs being developed. The Commission would have opportunities for review and final say in how this activity expands to other areas and how it is ultimately reflected in regulations and for each design via the normal licensing or certification processes.

RECOMMENDATION:

The staff recommends that the Commission approve the general, technology-inclusive approach for establishing functional containment performance criteria.

RESOURCES:

Resources required for each option are discussed in the enclosure, which is not publicly available.

Enclosures:
1. Background
2. Technology-Inclusive, Risk-Informed, Performance-Based Approach

Functional Containment Performance Criteria
Background

One of the fundamental safety functions to be addressed for any nuclear reactor is limiting the release of radioactive materials from the facility. The designs of the containment systems for most plants licensed by the U.S. Nuclear Regulatory Commission (NRC) serve to reduce the consequences of a defined postulated accident so that a particular facility may fulfill siting requirements as defined in the *Code of Federal Regulations*. The design basis accidents for large light-water reactors (LWRs) include loss of coolant accidents with breaks in piping containing water at high temperatures and pressures. The need for the containment structures to retain radioactive materials following a break of a pipe with high-energy fluid led to the development of the pressure retaining (large dry) and pressure-suppression containment designs used for LWRs.[1] Non-LWR technologies have operating conditions, coolants, and fuel forms that are different from LWRs. These differences may allow, or possibly require, different approaches to fulfilling the safety function of limiting the release of radioactive materials.

The U.S. Atomic Energy Commission (AEC) established various rules and guidance for designing, siting, constructing, and operating the first commercial reactors. Many of the NRC's current regulations and practices can be traced to those first defined by the AEC in the early 1960s. Like today, the early development of commercial nuclear power included consideration of many technologies and designs. A useful history related to the development of containment designs is provided in a report prepared in 1965 for the AEC by the Nuclear Safety Information Center (NSIC) at Oak Ridge National Laboratory (ORNL). The report, ORNL-NSIC-5, "U.S. Reactor Containment Technology - a Compilation of Current Practice in Analysis, Design, Construction, Test, and Operation," defined reactor containment as follows:

> Reactor containment is a general term which, for the purpose of this report, is defined to include all structures, systems, mechanisms, and devices that can be provided to attain with a high degree of reliability some specified attenuation in the radioactivity presumed to be released from the primary system in a reactor accident and might otherwise be released to the surrounding environment. Most containment enclosures generally incorporate some radiation shielding in order to restrict the direct radiation exposure therefrom in the event of a major fission-product release. Containment is usually not required for routine operations and need not be absolute, and, in fact, generally is not. Containment systems are normally referred to as "leak-tight" structures, which, in reality, leak a finite amount. Thus, as a consequence, containment systems may consist of integrated complexes of structures, processes, and subsystems, which combine to control the activity release in a prescribed manner with a high degree of reliability. To the extent that activity may also be released from refueling buildings and chemical processing plants, similar containment and other engineered safeguard features are commonly provided with these facilities also.

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1 Requirements and practices for LWRs have evolved over decades and have increasingly considered events beyond those originally used to establish plant design features. Venting of LWR containments is an element within severe accident management guidelines for operating pressurized and boiling water reactors, which were developed as part of the response to the accident at Three Mile Island. The possible need to vent containments to avoid an uncontrolled release of radioactive material from a failed containment is also included in severe accident management from advanced LWRs and previous non-LWR designs reviewed by the NRC (e.g., Clinch River Breeder Reactor).

ORNL-NSIC-5 summarizes the containment designs provided for early plants and those developed for the first generation of commercial nuclear plants. The report offers possible approaches for non-LWRs to reflect the specific coolants and operating conditions associated with gas-cooled and sodium-cooled reactors. A pressure-venting or pressure-relieving containment design is mentioned in the report as a likely candidate for gas-cooled reactors. A pressure-venting containment design was subsequently used for the Fort St. Vrain high-temperature gas-cooled reactor (HTGR), which was licensed by the AEC and operated from 1979 to 1989.

The NRC has engaged in several pre-licensing interactions and developed policies and guidance to support the potential licensing of advanced reactor facilities. The NRC's Policy Statement on the Regulation of Advanced Reactors was first issued on July 8, 1986 (51 FR 24643) with an objective to provide all interested parties, including the public, with the Commission's views concerning the desired characteristics of advanced reactor designs. The policy statement identifies attributes that should be considered in advanced designs, including highly reliable and less complex heat removal systems, longer time constants before reaching safety system challenges, reduced potential for severe accidents and their consequences, and use of the defense-in-depth philosophy of maintaining multiple barriers against radiation release. The NRC solicited stakeholder views on several questions during the development of the policy statement and included the section "Commission Position Regarding Policy Statement Questions" when the policy statement was issued. The following Commission Position is of particular relevance to the current activities and addressing functional containment performance requirements:

> *Question 1:* Should NRC's regulatory approach be revised to reduce dependence on prescriptive regulations and, instead, establish less prescriptive design objectives, such as performance standards? [2] If so, in what aspects of nuclear power plant design (For Example, reactor core power density, reactor core heat removal, containment, and siting) might the performance standards approach be applied most effectively? How could implementation of these performance standards be verified?
>
> *Commission Response:* Many of the Commission's existing regulations, criteria, and guidelines are of a nonprescriptive nature, and the extent to which the Commission's proposed safety goals, (which are also of a nonprescriptive nature) will be used in the regulation of nuclear reactors is currently being evaluated. In the review and regulation of advanced reactors the Commission intends to make use of existing and future regulations where they are applicable to advanced reactors. Many such regulations are expected to be of a nonprescriptive nature. The areas where existing regulations and guidelines would be used include: quality assurance, equipment qualification, external events, sabotage, fire protection, radiation protection, and operator training and qualification. In developing additional criteria and guidance to address those characteristics which differ from LWRs less prescriptive criteria will be considered. The use of less prescriptive criteria will depend upon the design in question and the ability to verify compliance with the criteria. Advanced reactor designers are encouraged

[2] Additional information on the distinctions between prescriptive and performance-based approaches can be found in a 1999 Commission-approved white paper (ADAMS Accession No. ML003753601) and NUREG/BR-0303, "Guidance for Performance-Based Regulation" (ADAMS Accession No. ML023470659).

as part of their design submittals to propose specific review criteria or novel regulatory approaches which NRC might apply to their designs.

The NRC interacted with the Department of Energy (DOE) and reactor developers in the late 1980s and early 1990s regarding the potential licensing of non-LWR designs. These activities resulted in the publication of assessments such as NUREG-1368, "Preapplication Safety Evaluation Report for the Power Reactor Innovative Small Module (PRISM) Liquid-Metal Reactor," and NUREG-1338, "Draft Preapplication Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor." The NRC staff identified a number of potential policy issues during the assessments of advanced reactor designs. The staff included the following proposal for performance criteria for containments in SECY-93-092, "Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, AND PIUS) and CANDU 3 Designs and Their Relationship to Current Regulatory Requirements" (ADAMS Accession No. ML040210725):

<u>CONTAINMENT:</u>
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. The staff intends to approach this by comparing containment performance with the accident evaluation 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 this paper within their design envelope.[3]

- For a period of approximately 24 hours following the onset of core damage, the specified containment challenge event results in no greater than the limiting containment leak rate used in evaluation of the event categories, and structural stresses are maintained within acceptable limits (i.e., ASME Level C requirements or equivalent). After this period, the containment must prevent uncontrolled releases of radioactivity.

The Commission approved the staff's proposed approach for considering containment functional performance during the pre-application interactions in the Staff Requirements Memorandum (SRM) dated July 30, 1993 (ADAMS Accession No. ML003760774).

Policy issues related to non-LWRs were again brought to the Commission's attention in SECY-03-0047, "Policy Issues Related to Licensing Non-Light-Water Reactor Designs" (ADAMS Accession No. ML030160002). The containment-related issue centered on the question of under what conditions can a plant be licensed without a pressure retaining containment building (i.e., a confinement building instead of a containment). The staff made the following recommendation:

The staff recommends that the Commission take the following actions:

[3] The various sections of SECY-93-092 describe the relationships and dependencies between issues such as licensing basis events, source terms, and containment performance criteria. These same relationships were discussed in the follow-up paper SECY-03-0047 and are also reflected in the more recent activities related to the Next Generation Nuclear Plant (NGNP) and the staff's current proposal described in Enclosure 2.

- Approve the use of functional performance requirements to establish the acceptability of a containment or confinement structure (i.e., a non-pressure retaining building may be acceptable provided the performance requirements can be met).

- If approved by the Commission, develop the functional performance requirements using as a starting point guidance contained in the Commission's July 30, 1993, SRM and the Commission's guidance on the other issues contained in this paper.

In the SRM for SECY-03-0047 dated June 26, 2003 (ADAMS Accession No. ML031770124), the Commission stated:

> The Commission has disapproved the staff's recommendation for issue 6 related to the requirement for a pressure retaining containment building. At this time there is insufficient information for the Commission to prejudge the best options and make a decision on the viability of a confinement building. The staff should develop performance requirements and criteria working closely with industry experts (e.g., designers, EPRI, etc.) and other stakeholders regarding options in this area, taking into account such features as core, fuel, and cooling systems design. The staff should pursue the development of functional performance standards and then submit options and recommendations to the Commission on this important policy decision.

The staff updated the Commission 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," on the development of a technology neutral framework and possible approaches to resolve policy issues remaining from SECY-03-0047. The paper used the terminology of the time in referring to the issue as "containment versus confinement" and described possible performance criteria with a preference for the following:

> 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 (including within the design-basis category, selected credible events having the potential for high consequence source terms) and have the capability to establish controlled leakage and controlled release of delayed accident source term radionuclides.

SECY-05-0006 noted that there was no consensus among stakeholders on a single descriptive term such as "containment," "confinement," "vented low-pressure containment," "reactor building" or "containment structure." Stakeholders indicated that each term implied a specific reactor technology with specific functions and specific functional performance requirements and criteria that were not necessarily applicable to every new reactor technology. However, regardless of the term, all "containment" designs provide or support accident prevention functions and accident mitigation functions. These functions are provided by a combination of civil structures (e.g., buildings) and systems. The paper identified technology-neutral functions and possible technology-neutral functional performance requirements and criteria for the containment.

As a follow-up to SECY-05-006, the NRC addressed the concept of functional containment and related advanced reactor issues, such as ensuring sufficient defense in depth, in an advanced notice of proposed rulemaking (ANPR) published on May 4, 2006 (71 FR 26267). In the ANPR, the NRC asked for stakeholder feedback on questions related to containment functional performance standards. In SECY-07-0101, "Staff Recommendations Regarding a Risk-Informed and Performance-Based Revision to 10 CFR Part 50," dated June 14, 2007 (ADAMS Package Accession No. ML070790253), the NRC staff requested that the Commission defer the rulemaking activity until after the development of the licensing strategy for the NGNP or receipt of an application for design certification or a license for the Pebble Bed Modular Reactor. In the SRM for SECY-07-0101 (ADAMS Accession No. ML072530501), the Commission approved the NRC staff's recommendation to defer the rulemaking activity. Subsequent changes to the NGNP project ultimately led to the rulemaking activities being discontinued.

Although the NRC did not pursue a rulemaking as envisioned in SECY-05-0006 and subsequent ANPR, the staff continued interactions with stakeholders on policy issues related to advanced reactors. These interactions centered on the NGNP project and a series of white papers intended to help resolve key licensing issues, including functional containment performance criteria. Following interactions with DOE, Idaho National Laboratory (INL), and the Advisory Committee on Reactor Safeguards (ACRS), the NRC staff provided feedback on the white papers to DOE's Office of Nuclear Energy In a letter dated July 17, 2014 (ADAMS Accession No. ML14174A734). Enclosure 1 to that letter (ADAMS Accession No. ML14174A774) summarized the staff's views on four key licensing issues and offered the following on DOE's request to establish options on functional containment performance standards:

> The concept of performance-based containment acceptability for a modular HTGR has been well established by the Commission in response to SECY-93-092 and SECY-03-0047. The Commission-approved performance-based containment concept specifically does not require a pressure-retaining shielded containment structure similar to that used in current large LWR plants. In its SRM to SECY-03-0047, the Commission directed the staff to pursue the development of containment functional performance standards and to submit options and recommendations to the Commission for a future policy decision.
>
> SECY-05-0006 is a policy issue information paper that describes the staff's work on several issues that were considered in the development of a future technology-neutral framework for reactor licensing, including the Commission-requested efforts on containment functional performance. However, as with the other issues discussed in SECY-05-0006, the staff did not submit the technology-neutral functional containment performance requirements and criteria options outlined in SECY-05-0006 for a Commission policy decision. It may be appropriate for the Commission to review the specific criteria applied to evaluate a modular HTGR functional containment concept for both a prototype plant and subsequent standard plants.
>
> Consistent with the positions presented in SECY-05-0006, the staff agrees with the following description of a performance standard for a functional containment, which DOE/INL provided during assessment interactions in July and October 2012 (ML12223A151, ML13198A115):
>
>> The upper tier performance standard for the functional containment for the NGNP should be to ensure the integrity of the fuel particle barriers

(i.e., the kernel and coatings of the TRISO-coated fuel particles) rather than to allow significant fuel particle failures and then need to rely extensively on other mechanistic barriers (e.g., the helium pressure boundary and the reactor building). This standard should be characterized by [the following]:

- [Ensuring] radionuclide retention within fuel during normal operation with relatively low inventory released into the helium pressure boundary (HPB).

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

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

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

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

In July 2013, DOE and the NRC established a joint initiative to address how the general design criteria (GDC) in Appendix A, "General Design Criteria for Nuclear Power Plants," of Title 10 of the *Code of Federal Regulations*, Part 50 "Domestic Licensing of Production and Utilization Facilities" (10 CFR Part 50) may be adapted for non-LWR designs. The guidance is intended to be used by non-LWR reactor designers, applicants, and licensees to develop principal design criteria (PDC) for any non-LWR design, as required by the applicable NRC regulations. DOE developed and provided to the NRC staff the report titled, "Guidance for Developing Principal Design Criteria for Advanced (Non-Light Water) Reactors" in December 2014. NRC staff had numerous interactions with stakeholders on the DOE report and draft staff-prepared criteria during the development draft regulatory guide DG-1330, "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors. DG-1330 was issued for public comment in February, 2017. The staff dispositioned the public comments received on DG-1330 and issued *Regulatory Guide (RG) 1.232,* "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors" in *MONTH 2018.* The RG includes acceptable design criteria (DC) for any non-LWR technology (advanced reactor design criteria or ARDC) as well as criteria developed for two specific technologies, sodium-cooled fast reactors (SFRs) and MHTGRs. Criterion 16, "Containment design," for the three technology categories are provided below:

ARDC
(same as GDC)
Reactor containment and associated systems shall be provided to establish an essentially leak-tight barrier against the uncontrolled release of radioactivity to the environment and to assure that the containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.

SFR
A reactor containment consisting of a low-leakage, pressure-retaining structure surrounding the reactor and its primary cooling system shall be provided to control the release of radioactivity to the environment and to ensure that the reactor containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.

The containment leakage shall be restricted to be less than that needed to meet the acceptable onsite and offsite dose consequence limits, as specified in 10 CFR 50.34 for postulated accidents.

MHTGR
A reactor functional containment, consisting of multiple barriers internal and/or external to the reactor and its cooling system, shall be provided to control the release of radioactivity to the environment and to ensure that the functional containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.

The RG provides the following rationale for MHTGR-16:

> The term "functional containment" is applicable to advanced non-LWRs without a pressure retaining containment structure. A functional containment can be defined as "a barrier, or set of barriers taken together, that effectively limit the physical transport and release of radionuclides to the environment across a full range of normal operating conditions, AOOs, and accident conditions."
>
> Functional containment is relied upon to ensure that dose at the site boundary as a consequence of postulated accidents meets regulatory limits. Traditional containment structures also provide the reactor and SSCs important to safety inside the containment structure protection against accidents related to external hazards (e.g., turbine missiles, flooding, aircraft).
>
> The MHTGR functional containment safety design objective is to meet 10 CFR 50.34, 52.79, 52.137, or 52.157 offsite dose requirements at the plant's exclusion area boundary (EAB) with margins.
>
> The NRC staff has brought the issue of functional containment to the Commission, and the Commission has found it generally acceptable, as indicated in the staff requirements memoranda (SRM) to SECY-93-092 (Ref. 8) and SECY-03-0047 (Ref. 9). In the SRM to SECY-03-0047 (Ref. 10), the Commission instructed the staff to "…develop performance requirements and criteria working closely with industry experts (e.g., designers, EPRI, etc.) and other stakeholders regarding options in this area, taking into account such

> features as core, fuel, and cooling systems design," and directed the staff to submit options and recommendations to the Commission for a policy decision.
>
> The NRC staff also provided feedback to the DOE on this issue as part of the NGNP project. In the NRC staff's "Summary Feedback on Four Licensing Issues NGNP" (Ref. 11), the area on functional containment and fuel development and qualification noted that "…approval of the proposed approach to functional containment for the MHTGR concept, with its emphasis on passive safety features and radionuclide retention within the fuel over a broad spectrum of off-normal conditions, would necessitate that the required fuel particle performance capabilities be demonstrated with a high degree of certainty."
>
> GDC 38, 39, 40, 41, 42, 43, 50, 51, 52, 53, 54, 55, 56, and 57 are not applicable to the MHTGR design, since they address design criteria for pressure-retaining containments in the traditional LWR sense. Requirements for the performance of the MHTGR reactor building are addressed by new Criterion 71 (design basis) and Criterion 72 (provisions for periodic testing and inspection).

The staff's rationale for referring to the current GDC 16 for the ARDC is described in the RG as follows:

> For non-LWR technologies, other than SFRs and MHTGRs, designers may use the current GDC to develop applicable principal design criteria. However, it is also recognized that characteristics of the coolants, fuels, and containments to be used in non-LWR designs could share common features with SFRs and MHTGRs. Hence designers may propose using the SFR-DC-16 or MHTGR-DC 16 as appropriate. Use of the MHTGR-DC 16 will be subject to a policy decision by the Commission.

Completing the non-LWR design criteria has been an important first step to address the unique characteristics of non-LWR technology. At the same time, the NRC acknowledged the future benefits to further risk informing the non-LWR design criteria and recognizes the possibility of either revising the RG or accepting alternative DC in other guidance documents or applications. ARDC 16 is an example of guidance that could be revised or supplemented as a result of Commission direction to resolve key policy and technical issues.

The NRC staff is continuing to interact with DOE, non-LWR designers, and other stakeholders to resolve a variety of policy issues and develop guidance for a flexible non-LWR regulatory review process. Stakeholders identified the resolution of remaining issues related to functional containment performance criteria as an important item to enable developers to make critical design and licensing decisions. However, the interrelationships between various policy and technical issues makes it difficult to resolve any specific matter in isolation. The NRC staff are currently working on multiple activities defined within the program documents "NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness" (ADAMS Accession No. ML16356A670) and ""NRC Non-Light Water Reactor Near-Term Implementation Action Plans" (ADAMS Accession No. ML17165A069). The interrelationships and need to develop an integrated approach for non-LWRs is reflected in the NRC staff giving priority to Strategies 3 (flexible regulatory review process) and 5 (identify and resolve policy issues) in the implementation action plans. The desire to develop an integrated and technology-inclusive approach are also reflected in Enclosure 2, which proposes a methodology for determining appropriate performance measures for functional containments for any non-LWR technology or design.

Functional Containment Performance Criteria
Technology-Inclusive, Risk-Informed, Performance-Based Approach

Introduction

The staff described efforts to prepare for possible licensing of non-light water reactor (non-LWR) technologies in “NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness,” (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16356A670). The staff developed implementation action plans (IAPs) to identify specific activities that the NRC will conduct in the near-term, mid-term, and long-term timeframes (ADAMS Accession Nos. ML17165A069 and ML17164A173). The IAPs included the following strategies to meet the objective of achieving regulatory readiness:

Strategy 3: Develop guidance for a flexible non-LWR regulatory review process within the bounds of existing regulations, including the use of conceptual design reviews and staged-review processes

Strategy 5: Identify and resolve technology-inclusive policy issues that impact the regulatory reviews, siting, permitting, and/or licensing of non-LWR nuclear power plants (NPPs)

Contributing activities related to these strategies include:

- Establish and document the criteria necessary to reach a safety, security, or environmental finding for non-LWR applicant submissions. The criteria and associated regulatory guidance are available to all internal and external stakeholders.

- Determine and document appropriate non-LWR licensing bases and accident sets for highly prioritized non-LWR technologies.

- Identify, document and resolve (or develop plan to resolve) current regulatory framework gaps for non-LWRs.

- Analyze and resolve technology-inclusive non-LWR policy issues

Background information on the policy issues related to non-LWR design features serving to limit the release of fission products is provided in Enclosure 1. Much of the discussion on this topic has been focused on high-temperature gas-cooled reactor (HTGR) technologies and the roles of the fuel coatings and reactor building to contain or confine radioactive materials. The policy issue addressing the retention of fission products using a “functional containment” versus a prescriptive requirement for an essentially leak tight building was partially resolved in previous papers and Commission decisions. An important item remaining to be fully resolved is to define appropriate performance criteria for design features serving to limit the release of radioactive materials. The NRC and reactor developers have long recognized the need to resolve this issue to support further development and licensing of HTGRs. Current activities related to advanced reactors includes a large number of non-LWR technologies and designs, including molten-salt reactors (MSRs). The NRC staff routinely meets with developers and other stakeholders in the advanced reactor community. The stakeholders identified during these interactions that resolving remaining issues of functional containment performance criteria is an important item to support further development of various non-LWR designs.

The resolution of this issue also supports ongoing activities on Strategy 3 related to establishing criteria for safety decisions, identifying appropriate licensing basis and accident sets, and resolving current regulatory gaps. As described in the IAPs, the staff's efforts to better define an overall licensing framework for non-LWRs are a logical extension of other efforts to better incorporate risk-informed, performance-based approaches into the regulatory process. Such efforts for light water SMRs is described in SECY-11-0024, "Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews," dated February 18, 2011 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML110110688). The integrated framework described in SECY-11-0024 were subsequently incorporated into guidance documents such as the introduction to NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition." The current interactions with stakeholders in the non-LWR community provides an opportunity to consider various interrelated issues and to coordinate the resolution of performance criteria for retaining radioactive materials within reactor facilities with efforts such as defining licensing basis events and evaluating emergency planning zones.

DISCUSSION

Enclosure 1 provides a summary of the historical discussions and interactions related to the policy issues on design features for limiting the release of fission products from non-LWR designs. Many aspects of those discussions are rooted in how requirements evolved for the currently operating large LWRs and the role of pressure-retaining or pressure-suppression containment buildings for both design-basis accidents and beyond-design-basis events. At the same time, the previous papers on this topic acknowledge that non-LWRs designs would include different events and phenomena, and would reflect attributes identified in NRC's Policy Statement on the Regulation of Advanced Reactors (73 FR 60612). The staff included the following recommendation in SECY-93-092, "Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and PIUS) and CANDU 3 Designs and Their Relationship to Current Regulatory Requirements," dated April 8, 1993 (ADAMS Accession No. ML040210725).

> Containment:
>
> 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. The staff intends to approach this by comparing containment performance with the accident evaluation 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 [Accident Evaluation] to this paper within their design envelope.

- For a period of approximately 24 hours following the onset of core damage, the specified containment challenge event results in no greater than the limiting containment leak rate used in evaluation of the event categories, and structural stresses are maintained within acceptable limits (i.e., ASME Level C requirements or equivalent). After this period, the containment must prevent uncontrolled releases of radioactivity.

The Commission approved the staff's recommendations in the Staff Requirements Memorandum (SRM) dated July 30, 1993 (ADAMS Accession No. ML003760774). The staff subsequently recommended in SECY-03-047, "Policy Issues Related to Licensing Non-Light- Water Reactor Designs" (ADAMS Accession No. ML030160002), that the Commission approve the use of functional performance requirements to establish the acceptability of a containment or confinement structure. The Commission stated the following in the associated SRM (ADAMS Accession No. ML031770124).

> The Commission has disapproved the staff's recommendation for issue 6 related to the requirement for a pressure retaining containment building. At this time there is insufficient information for the Commission to prejudge the best options and make a decision on the viability of a confinement building. The staff should develop performance requirements and criteria working closely with industry experts (e.g., designers, EPRI, etc.) and other stakeholders regarding options in this area, taking into account such features as core, fuel, and cooling systems design. The staff should pursue the development of functional performance standards and then submit options and recommendations to the Commission on this important policy decision.

Since the early 2000's, the staff has interacted with stakeholders and made progress in areas directly and indirectly related to developing functional performance standards for design features serving to retain radioactive materials within non-LWR facilities. The use of risk-informed, performance-based approaches within licensing decisions and other regulatory areas has continued to evolve for operating reactors and for reactor designs being developed. The NRC worked closely with DOE to develop a licensing strategy for the Next Generation Nuclear Plant (NGNP) Program and the staff reviewed major elements of a licensing framework for the related HTGR designs. The NRC also identified and responded to lessons learned from events such as the terrorists' attacks in 2001 and the Fukushima accident in 2011. The evaluation and response to the lessons learned from these events included a more integrated approach to considering risks and ensuring appropriate measures were in place to prevent or mitigate events potentially involving losses of safety functions and control of radioactive materials.

Figure 1 shows a general risk assessment approach[4] with consideration of a basic hazard such as radioactive materials; measures or barriers to prevent a top-level event such as core damage in a LWR or equivalent damage state for non-LWRs; and mitigation or recovery measures such as severe accident design features, siting and emergency planning. The staff is currently interacting with advanced reactor stakeholders regarding various areas represented in the

[4] ISO-31010, "Risk management – Risk assessment techniques" describes the process as: "Bow tie analysis is a simple diagrammatic way of describing and analyzing the pathways of a risk from causes to consequences. It can be considered to be a combination of the thinking of a fault tree analyzing the cause of an event (represented by the knot of a bow tie) and an event tree analyzing the consequences. However the focus of the bow tie is on the barriers between the causes and the risk, and the risk and consequences."

figure. Examples include interactions with the joint DOE/industry Licensing Modernization Project in developing approaches to identify and address plant internal events and external events, developing security design considerations and exploring possible alternatives to current security requirements, assessing siting-related guidance, and developing a proposed rule with alternative requirements for emergency planning zones. The interrelationships between these activities and with the associated performance criteria for design features used to retain radioactive materials within a plant require an integrated approach to resolving issues and developing a regulatory framework for non-LWRs.

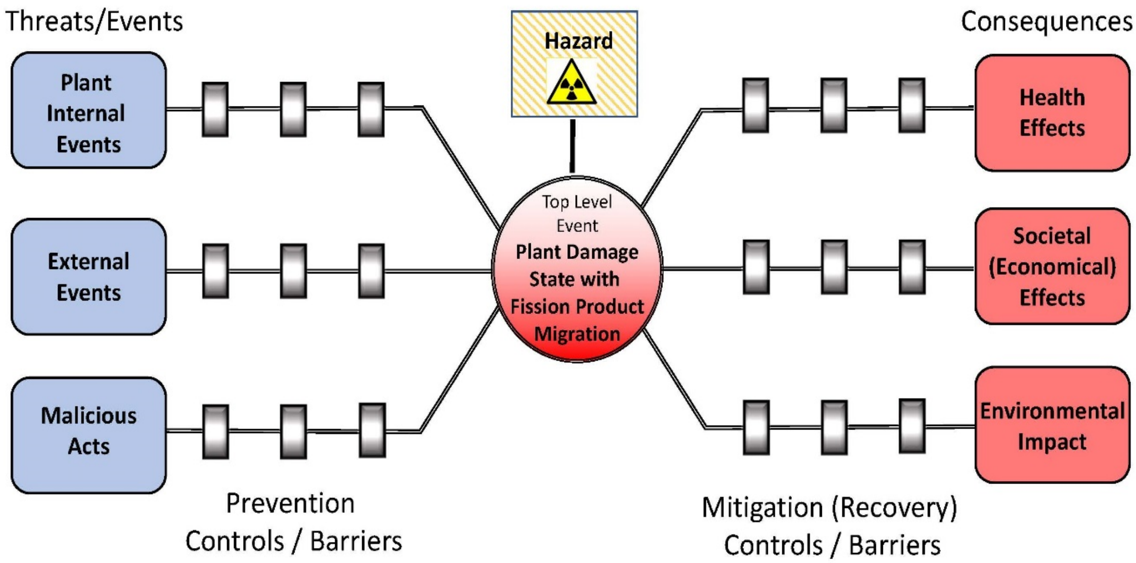

Figure 1: Risk Management - Barrier Assessment (Bow Tie) Method

The integrated methodology represented in Figure 1 is consistent with NRC's longstanding policies to use risk-informed performance-based approaches for decision-making and establishing regulatory requirements. Additional levels of analyses are performed to assess various controls and barriers in terms of their availability and capability to prevent or mitigate releases. Developers of specific reactor designs consider the potential consequences associated with a reactor technology and power level, which corresponds to the hazard in Figure 1, and are able to assess the benefits and related costs of potential barriers to prevent or mitigate a plant damage state comparable to core damage used for LWRs. The number and nature of barriers is based on the identified events, the underlying hazard (i.e., amount and form of radioactive materials), and the uncertainties associated with capabilities and availability of other controls and barriers.

The staff described in previous papers provided to the Commission that the performance criteria for what was termed "functional containment" design features were tied to radionuclide release limits for various event categories. The discussions often consisted of comparing the roles and characteristics of the physical enclosure for a non-LWR to the primary containment buildings for LWRs. Such discussions led to expressions such as "functional containment" and "containment versus confinement" related to the design of HTGRs and other non-LWR technologies. Remaining questions about "functional containment" performance criteria hamper the ability of reactor developers to make critical design decisions. The contributing activities for Strategy 3 within the staff’s IAPs are intended to reduce such regulatory uncertainties facing developers of non-LWR designs. The specific activities include interactions with stakeholders and recognize that an integrated approach is needed such that developers can effectively assess features to manage risks to the public and the associated costs of possible prevention or mitigation barriers. This paper defines a general structure of a larger, technology-inclusive framework from which logical performance criteria are derived for specific design features. Additional details related to the framework will be developed through interactions with stakeholders and will be provided to the Commission in subsequent papers. However, now is an appropriate time to address how performance criteria would be defined – including those for “functional containment.”

The near-term IAPs include activities that can be pursued largely within the bounds of existing regulations. The staff’s interactions with stakeholders such as the Licensing Modernization Project are taking advantage of existing regulations, the work completed under the NGNP Program, and lessons learned from light-water SMR and non-LWR projects. The NRC-DOE joint initiative to develop sets of advanced reactor design criteria are an example of current activities and progress in this area. The staff’s interactions with stakeholders during the development of *Regulatory Guide (RG) 1.232,* "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors",” resulted in the following design criterion and supporting rationale for “functional containment” for modular high-temperature gas-cooled reactors:

> Containment design.
> A reactor functional containment, consisting of multiple barriers internal and/or external to the reactor and its cooling system, shall be provided to control the release of radioactivity to the environment and to ensure that the functional containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.
>
> Rationale
> The term “functional containment” is applicable to advanced non-LWRs without a pressure retaining containment structure. A functional containment can be defined as “a barrier, or set of barriers taken together, that effectively limit the physical transport and release of radionuclides to the environment across a full range of normal operating conditions, AOOs [anticipated operational occurrences], and accident conditions.”

The general approach described below elaborates on the discussions in SECY-03-047 and Regulatory Guide (RG) 1.232. The basic framework is built around the identification and categorization of licensing-basis events. Like the system that has evolved for operating reactors, event categories are developed considering factors such as estimated frequencies. Acceptance criteria are defined for each category considering potential consequences and ensuring sufficient defense in depth within the design and operation of any nuclear power plant. As described in the licensing strategy for the NGNP Project, there is general consensus between the NRC staff and stakeholders on identifying events using a combination of risk assessment tools (e.g., probabilistic risk assessment (PRA)) and deterministic methods, including engineering judgment. The staff has found that the inclusion of both considerations – risk assessments and deterministic methods – is necessary and sufficient to overcome occasional differences in emphasis on one element versus the other.

Figure 2 shows the logic for categorizing events developed by the Licensing Modernization Project starting from the structure used within the NGNP Program. The approach is similar to what has evolved for LWRs with some adjustments to more clearly address low-frequency events and to be technology-inclusive for various non-LWR designs. The figure, generally referred to as a frequency-consequence (F/C) curve, is being provided to illustrate the general organization of events but the staff is not ready to request Commission-level decisions on the specifics within the figure. The staff is continuing to interact with stakeholders to reach alignment on some topics such as the demarcation of categories and ensuring consistency across the assessments of prevention and mitigation controls and barriers for various events and consequences. These interactions are not expected to result in changes to the general approach or overall organization of events. The structure is sufficiently defined to show the categories and how related acceptance criteria would be derived along with additional consideration of deterministic methods to address uncertainties and ensure sufficient defense in depth. The NRC needs to establish an agreed upon general structure for event categories to support defining the role and performance criteria for design features serving to retain radioactive materials within non-LWR facilities.

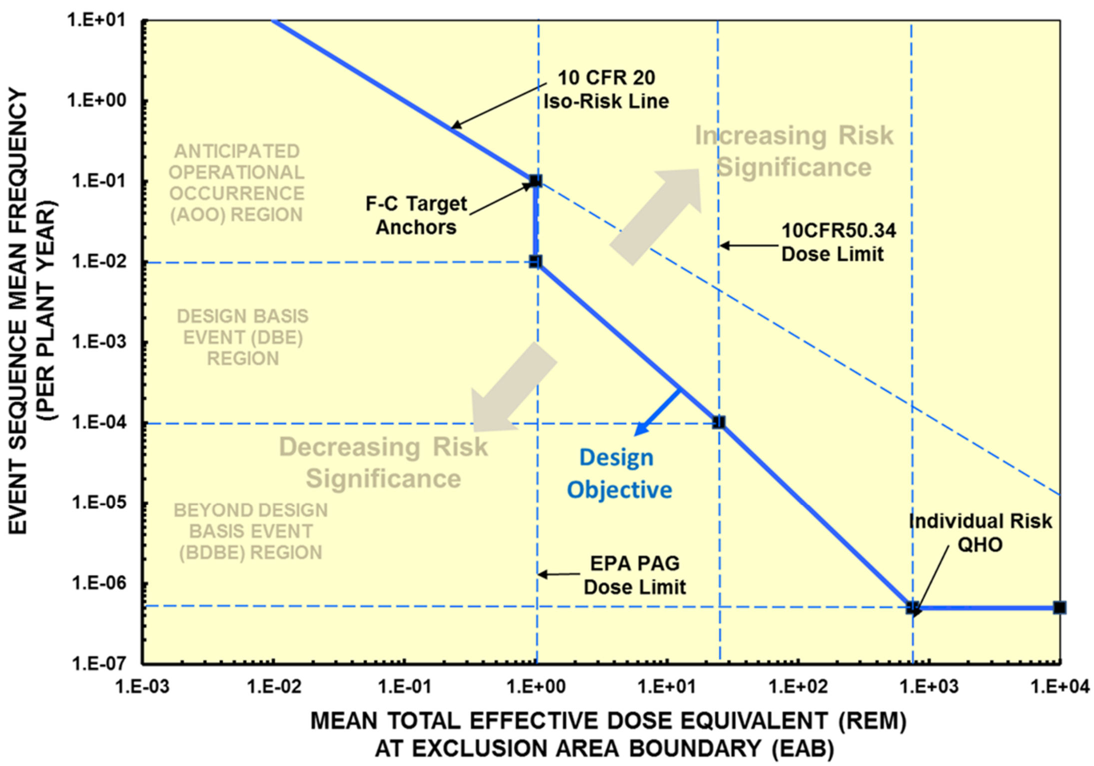

Figure 2 – Licensing Modernization Project Licensing Basis Event Categories and Frequency-Consequence Target

The staff proposes for the baseline framework for non-LWRs to adopt the set of event categories developed under the NGNP Program and continued in current interactions with the Licensing Modernization Project. Although the structure and terminology differ slightly from the current system for LWRs, each category in Table 1 has accepted high-level performance criteria that generally align with current requirements and practices. The event categories are described in Table 1:

Table 1 – Non-LWR Event Categories	
Category	Description
Normal Operations	Normal operations define initial conditions for licensing basis events. Radiological doses resulting from normal operation are controlled by limiting routine effluent releases to below regulatory requirements (i.e., Part 20 limits)
Anticipated Operational Occurrences (AOOs)	AOOs encompass planned and anticipated events (e.g., frequencies exceed approximately 10^{-2} per plant-year). The radiological doses from AOOs are required to meet a fraction of the normal operation public dose requirements (i.e., Part 20 limits) which are established for annual dose rates due to both events and planned effluent releases. AOOs are used to set operating limits for normal operation modes and states, and historically used to establish performance criteria for reactor protection systems. Design features and programmatic controls are established to limit AOO frequencies and consequences in terms of offsite doses and success of preventive controls and barriers (e.g., integrity of fuel cladding or coatings).
Design Basis Events (DBEs)	Design Basis Events (DBEs) encompass unplanned off-normal events not expected in the plant's lifetime, but which might occur in the lifetimes of a fleet of plants (i.e., event frequencies in the range of 10^{-4} to 10^{-2} per plant-year). The radiological doses from DBEs are required to be a fraction of accident public dose requirements (e.g., 10 CFR 50.34) as shown on the sliding illustrative F-C target in Figure 2. Design features and programmatic controls are established to limit DBE frequencies and consequences in terms of offsite doses and success of preventive controls and barriers (e.g., integrity of fuel cladding or coatings). The identification and evaluation of DBEs provide input to the selection of design basis accidents (DBAs) discussed below.
Beyond Design Basis Events (BDBEs)	Beyond Design Basis Events (BDBEs) are rare off-normal events whose frequencies range from a very low value (e.g., approximately 10^{-7} or 10^{-8} per plant-year to 10^{-4} per plant-year. BDBEs are evaluated to ensure that they do not pose an unacceptable risk to the public and to provide input to the selection of DBAs. Design features and programmatic controls are established to limit BDBE frequencies and consequences in terms of offsite doses and success of preventive barriers (e.g., integrity of fuel cladding or coatings) or mitigation barriers (e.g., severe accident design features).
Design Basis Accidents (DBAs)	DBAs are the safety analysis report Chapter 15, "Accident Analyses," which are prescriptively derived from the DBEs by assuming that only SSCs classified as safety-related are available to deal with the event. The public consequences of DBAs are conservatively calculated and assessed against 10 CFR 50.34 limits, similar to DBAs analyses for existing LWRs. DBAs have historically been used to define safety margins for SSCs and establish limiting conditions for operation.

A methodology to define performance criteria for specific design features, such as those serving to limit the release of radionuclides (in terms of magnitude and timing) can be constructed based on the above event categories and the need to fulfill fundamental safety functions as currently incorporated into the NRC's general design criteria and similar international standards. The three fundamental safety functions are controlling reactivity, removing heat, and retaining radioactive materials.[5] Figure 3 shows a top-down approach to establishing performance criteria for plant features using accepted event categories and safety functions. For each event category, performance criteria would define specific functions to be performed by a structure, system, or component (SSC) of a facility, and the specific values or ranges of values chosen for controlling parameters as reference bounds for design. The design of each SSC would be determined based on the aggregation of performance requirements for each event category and fundamental safety function as well as other potential roles that a designer may choose for that SSC. In the case of a building surrounding a reactor system, Figure 3 lists several potential uses that are discussed later in this enclosure.

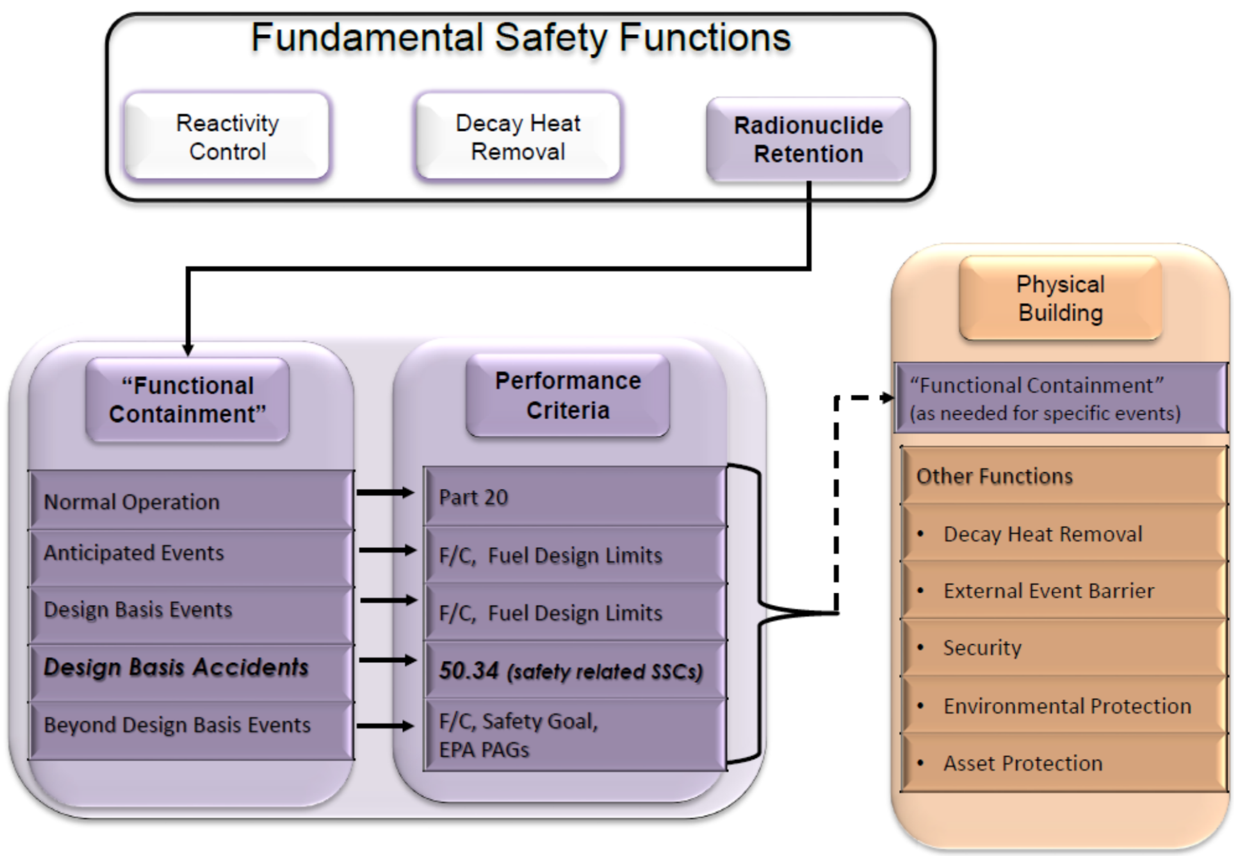

Figure 3: Derivation of Performance Criteria

5 The term fundamental safety functions is taken from International Atomic Energy Agency Specific Safety Requirements SSR-2/1, "Safety of Nuclear Power Plants: Design," and aligns with NRC requirements, such as the General Design Criteria for LWRs, which are organized in terms of "protection and reactivity control," "fluid systems," and "reactor containment." Whereas this paper is focused on functional containment and radionuclide retention, similar approaches are being defined for the other fundamental safety functions.

As can be seen from Figure 3, performance criteria for the design features associated with retaining radionuclides within a facility will be established based on the range of event categories and the related success criteria for each category. Plant equipment and normal operational controls are needed to limit effluent releases during normal operations and other limits on normal operations define possible initial conditions for other event categories. Success criteria for AOOs and DBEs include a graded scale for potential offsite doses based on event frequencies (i.e., below a frequency/consequence (F/C) target) and demonstration that prevention barriers limit the migration of fission products within the facility. Examples of acceptance criteria used for AOOs and DBEs include specified acceptable fuel design limits (SAFDLs) similar to LWRs and specified acceptable radionuclide release design limits (SARRDLs) used for HTGRs. DBAs are similar to current accident analyses described in Chapter 15 of safety analysis reports, which credit only safety related design features and show that offsite doses are below the regulatory limits in 10 CFR 50.34 (e.g., 25 Rem at exclusion area boundary over worst 2 hour period). BDBEs are assessed to ensure design features and programmatic controls keep the estimated frequencies and consequences below values corresponding to the NRC's safety goals, which are reflected in the F/C targets. It is anticipated that many non-LWR developers will incorporate design features to limit potential offsite doses to values below those that could justify alternative offsite emergency planning requirements (e.g., less than the Environmental Protection Agency (EPA) Protective Action Guidelines (PAGs). Requirements are defined for specific SSCs by aggregating the design features and programmatic controls needed to meet the success criteria for each event category. Establishing performance requirements for a set of event categories that extend from benign to severe supports the NRC philosophy of ensuring defense in depth and also generally aligns with standards and practices defined by the IAEA.

The above discussions highlight the interrelationships between functional containment performance criteria, performance criteria related to other barriers and fundamental safety functions, and the overall deployment goals being established for particular technologies or designs. An example is the relationships between performance criteria established for fuel design limits and those established for functional containments. SAFDLs are generally used as performance measures for reactor protection systems in LWRs and address specific physical phenomena such as departure from nucleate boiling or peak fuel temperatures that could damage fuel pellets or cladding during AOOs. Limiting the damage to fission product barriers such as fuel cladding during AOOs in turn limits the potential release of radionuclides to cooling systems and reliance on containments to retain radionuclides. Some non-LWR designs may not include a fuel cladding or have a distinct transition from effective to ineffective heat transfer such as departure from nucleate boiling. The SARRDL concept establishes limits on the possible increase in circulating radionuclide inventory during normal operations or an AOO (e.g., from fission product releases from coated fuel particles). Defining SARRDLs for specific designs is intertwined with functional containment performance criteria and would be developed by reactor designers as part of the integrated approach described in this paper. Plant operators would subsequently maintain plant configurations consistent with design and analysis limits by verifying fuel performance and location of radionuclide inventories.

The staff acknowledges that the above discussion establishes more of a performance-based methodology than a definitive or prescriptive set of performance criteria for "functional containment" or other design features. In addition, the staff is continuing interactions with stakeholders to reach agreement on several technical issues such as lower bounds for event frequencies and some details on establishing SARRDLs for non-LWR technologies. However, the NRC staff and non-LWR developers need to establish a logical path forward to complete the

Strategy 3 activities defined in the near-term IAPs and resolve interrelated policy issues such as establishing functional containment performance criteria. The need for an integrated and consistent approach to address both prevention barriers and mitigation barriers is especially important to developers needing to make key design decisions. The design decisions require an ability to assess tradeoffs between possible costs for various design features as well as possible operating and maintenance costs for prevention and mitigation barrier alternatives. Commission approval at this time of the general overall framework as it relates to "functional containment" performance criteria would allow the staff and stakeholders to continue interactions and resolve other technical and policy issues. The description of a performance-based methodology is appropriate given the variety of technologies and designs being developed. The Commission would have opportunities for review and final say in how this activity expands to other areas and how it is ultimately reflected in regulations and for each design via the normal licensing or certification processes.

OTHER REQUIREMENTS FOR PHYSICAL ENCLOSURES

Any commercial reactor is expected to have the coolant system and other key SSCs housed within some type of physical enclosure. If serving no other purpose, such an enclosure would serve to protect a valuable asset from the elements. Many discussions of "functional containment" and "containment versus confinement" have focused on the design attributes for the physical enclosure and its possible roles in providing defense in depth as a mitigation barrier for DBEs and BDBEs. As shown in Figure 3, a physical building could serve this purpose and have associated performance criteria based on the event category for which it is serving to limit the release radionuclides (in terms of magnitude and timing). The physical enclosure usually referred to as a primary containment structure for LWRs is safety related because of its role in DBAs and also has design features important for evaluating and protecting against BDBEs. The various reactor sizes and technologies being considered by non-LWR developers may or may not result in the need to credit design features of the physical enclosure for retaining radionuclides within the facility. The performance-based methodology previously discussed would determine what requirements were imposed on the physical enclosure for the fundamental safety function of retaining radionuclides. Examples in past interactions with non-LWR developers have included cases where attributes such as fuel form and system heat capacities reportedly limit the migration of radionuclides and alleviate the need for the design to credit physical enclosures retaining radionuclides for DBAs.

Whether or not a physical enclosure is needed to limit the release of radionuclides for one or more event categories, the staff and developers have recognized that structures may serve other purposes and be used to meet specific NRC regulations. The staff included discussions of such other purposes in papers such as SECY-2005-06, "Second Status Paper on the Staff's Proposed Regulatory Structure for New Plant Licensing and Update on Policy Issues Related to New Plant Licensing," dated January 7. 2005 (ADAMS Accession No. ML043560093). Examples of potential roles of physical enclosures beyond the retention of radionuclides include but are not limited to:

- Structural support to primary cooling systems;
- Supporting the decay heat removal fundamental safety function via structural support for and housing of backup or emergency cooling such as reactor cavity cooling systems;
- Prevention barrier against external events such as flooding and wind loadings;
- Design feature credited in aircraft impact assessments;
- Physical security design feature credited in preventing or delaying adversaries; and

- Design feature credited during environmental assessments of severe accident mitigation design alternatives.

In most examples, the physical enclosure is serving as or supporting a preventive barrier for the threats or events shown in Figure 1 (i.e., internal events, external events, and malicious acts). Performance criteria related to these functions (e.g., characteristics needed to address design basis flooding or wind loadings) would be added to requirements, if any, related to fulfilling the fundamental safety function of radionuclide retention. In such cases, an aggregation of performance requirements would determine the final design for a building or other physical enclosure. The consideration of various events and roles for SSCs and using various performance criteria to reach the final design of each SSC is consistent with current practices and the definition of the design basis for specific SSCs for currently operating plants.