ASME/ANS RA-S-1.1–2022

Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications

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FOREWORD

The American Society of Mechanical Engineers (ASME) Board on Nuclear Codes and Standards (BNCS) and American Nuclear Society (ANS) Standards Board have formed a Joint Committee on Nuclear Risk Management (JCNRM) to develop and maintain probabilistic risk assessment (PRA) standards. The JCNRM operates under procedures accredited by the American National Standards Institute (ANSI) as meeting the criteria of consensus procedures for American National Standards. The JCNRM holds two formal meetings per year, and users are invited to participate. Additional information about the JCNRM can be found on its committee page at https://cstools.asme.org/.

In 2002, ASME issued an initial PRA standard, the scope of which was Level 1 and large early release frequency for internal events at-power for light water reactor (LWR) nuclear power plants. In 2003 and 2007, ANS issued two other PRA standards, the scopes of which were external hazards and internal fires at-power for LWR nuclear power plants. In 2008, the three standards were combined into one standard, ASME/ANS RA-S–2008, under the joint auspices of ASME and ANS. A revision, ASME/ANS RA-Sa-2009 [Addendum (a)], was issued in 2009. The JCNRM came into existence after Addendum (a) was issued. A second revision was issued in 2013, ASME/ANS RA-Sb–2013 [Addendum (b)]. This revision was reaffirmed in 2018. A Case was issued in 2017, ASME/ANS RA-S CASE 1, which was an alternative to Part 5 (Seismic PRA). This was then reissued in 2019, ASME/ANS RA-S CASE 1-1, with only minor corrections.

ASME/ANS RA-S-1.1-2022 is a new edition of the Level 1 PRA Standard that supersedes all previous revisions. The JCNRM is responsible for ensuring that this Standard is maintained and revised, as necessary. This responsibility includes appropriate coordination with and linkage to other standards under development for related risk-informed applications.

ASME/ANS RA-S-1.1-2022 is a substantial revision of ASME/ANS RA-Sb-2013. The following major modifications are among those performed:

- A number of changes have been implemented to strengthen the consistency among technical elements that are cross-cutting through different hazards. These changes required, for example, revisiting Supporting Requirements (SRs) associated with screening, uncertainty, human reliability analysis, and documentation. The screening criteria are now consolidated into a single set of screening criteria in Part 1.
- Back references from Part to Part (e.g., from Part 4 to Part 2) have been made more consistent, deliberate, and explicit in each Part to facilitate the peer review process.
- Significant lessons learned have been gathered in the past few years on hazard PRAs such as high-winds PRAs and external flooding PRAs that previously had less opportunity for being piloted. Such lessons learned have been incorporated in clarifications of the intent of the SRs for Part 7 and Part 8.
- Capability Category III has been removed across the board on the basis that Capability Category II already envisions refined analysis and realism implemented for the risk-significant elements. Going beyond this, while not discouraged, is not something that needs to be codified in a standard that is supposed to identify the minimum requirements for a technically adequate analysis.
- The new edition of this Standard includes a new section in Part 1. Section 1-7 states requirements to assess the technical adequacy of newly developed methods to be used in the plant PRA.
- In previous addenda, Nonmandatory Appendix (NMA) 1-A provided examples of "PRA maintenance" and "PRA upgrades." These subjects are now being addressed by the Pressurized Water Reactor Owners Group (PWROG). The new NMA 1-A provides meanings for the action verbs used in SRs. It is provided as an aid to interpret the intent of the SRs, especially for users for whom English is not the first language.
- Key operating definitions such as the definitions of "PRA upgrade" and "PRA maintenance" have been changed. These definitions now agree with the ones presented in PWROG-19027-NP

(Rev. 2), "Newly Developed Method Requirements and Peer Review," and endorsed by the U.S. Nuclear Regulatory Commission via Regulatory Guide 1.200 (Rev. 3), "Acceptability of Probabilistic Risk Assessment Results for Risk-Informed Activities." Other definitions have been revisited for clarity.

- Notes and commentaries have been revised to ensure content is still up to date and, for the most part, are removed from the body of this Standard and located in NMAs associated with the individual Parts. This relocation emphasizes the concept that notes and commentaries do not represent formal requirements of this Standard and are provided for information. References are also removed from individual SRs and moved to notes as one way to meet the SRs.
- All peer review requirements have been consolidated into one section in Part 1 to remove inconsistencies and duplicated information from different Parts.
- The clarification regarding the scope of walkdowns documented in JCNRM Inquiry 20-2435 for Addendum B has been included in the NMAs for all walkdown SRs in this Standard. (Inquiry 20-2435 available at https://cstools.asme.org/csconnect/CommitteePages.cfm?Committee=100186782&Action=40886)
- Finally, Part 10 on the Seismic Margin Assessment has been withdrawn from the Standard and is therefore removed.

The current edition of this Standard has a significantly larger number of SRs, even though some have been removed. However, the intent of the overall Standard remains consistent with the previous versions.

This publication, the 2022 edition of the "Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications," was approved by the ASME BNCS and the ANS Standards Board. ASME/ANS RA-S-1.1-2022 was approved by ANSI on May 11, 2022.

CORRESPONDENCE WITH THE ASME/ANS JOINT COMMITTEE ON NUCLEAR RISK MANAGEMENT

General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions or a case, and attending Committee meetings. Correspondence should be addressed to:

Secretary, ASME/ANS Joint Committee on Nuclear Risk Management, The American Society of Mechanical Engineers
Two Park Avenue
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http://go.asme.org/Inquiry

Proposing Revisions. Revisions to the Standard are made periodically to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Interpretations. Upon request, the ASME/ANS JCNRM Standards Committee will render an interpretation of any requirement of the Standard. Interpretations can be rendered only in response to a written request sent to the Secretary of JCNRM.

Requests for interpretation should preferably be submitted through the online Interpretation Submittal Form. The form is accessible at http://go.asme.org/InterpretationRequest. Upon submittal of the form, the inquirer will receive an automatic e-mail confirming receipt.

If the inquirer is unable to use the online form, they may mail the request to the Secretary of JCNRM at the above address. The request for an interpretation should be clear and unambiguous. It is further recommended that the inquirer submit their request in the following format:

Subject	Cite the applicable paragraph number(s) and the topic of the inquiry in one or two words.
Edition	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. Please provide a condensed and precise question, composed in such a way that a "yes" or "no" reply is acceptable.
Proposed Reply(ies)	Provide a proposed reply(ies) in the form of "yes" or "no," with explanation as needed. If entering replies to more than one question, please number the questions and replies.
Background Information	Provide the Committee with any background information that will assist the Committee in understanding the inquiry. The inquirer may also include any plans or drawings that are necessary to explain the question; however, these materials should not contain proprietary names or information.

Requests that are not in the format described above may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

Moreover, ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the inquiry information submitted, it is the opinion of the Committee that the inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Furthermore, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Attending Committee Meetings. The JCNRM regularly holds meetings and/or telephone conferences that are open to the public. Persons wishing to attend any meeting and/or telephone conference should contact the Secretary of JCNRM.

Proposing a Case. Cases may be issued to provide alternative rules when justified, to permit early implementation of an approved revision when the need is urgent, or to provide rules not covered by existing provisions. Cases are effective immediately upon ASME approval and shall be posted on the ASME Committee web page.

Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the Standard and the paragraph, figure, or table number(s), and be written as a Question and Reply in the same format as existing Cases. Requests for Cases should also indicate the applicable edition(s) of the Standard to which the proposed Case applies.

JCNRM Cases may be issued periodically and are available under the "JCNRM CASES" tab in the lefthand column at https://go.asme.org/JCNRMcommittee.

ACKNOWLEDGMENTS

The ANS/ASME JCNRM is animated by the passion of more than 200 professionals in the industry, from four continents and spanning the extensive interdisciplinary breadth needed for the development of multihazard, full-scope, comprehensive risk assessments. Their dedication and support continue to sustain the primary role that risk information has in the safe and efficient design, operation, and regulation of nuclear power plants. The members of the JCNRM Subcommittee on Standard Maintenance and the reporting working groups have dedicated significant time to the refinement of this Standard.

A particular debt of gratitude is owed by the JCNRM to Paul Amico, Andrea Maioli, and Ian Wall, who have been instrumental in leading and coordinating the combined effort needed to update and edit this edition of the Standard, navigating the schedule and challenges of a volunteer organization while maintaining the highest technical rigor.

A number of people have supported the JCNRM for numerous years but retired before seeing the completion of this Standard, for which they provided instrumental help. We acknowledge the efforts of these people and especially the work of Gareth Perry, former Subcommittee on Standard Maintenance vice cochair.

We also remember dear friends and significant contributors to this Standard and to the risk-informed technology community that have passed. In memoriam, we acknowledge Mary Drouin, Barry Sloane, and Rupert Weston.

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Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications

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PART 1 GENERAL REQUIREMENTS FOR A LEVEL 1 PRA, INCLUDING LARGE EARLY RELEASE FREQUENCY

Section 1-1 Introduction

1-1.1 OBJECTIVE

This Standard states the requirements for probabilistic risk assessments (PRAs) used to support risk-informed decisions for commercial light water reactor (LWR) nuclear power plants while at-power.

1-1.2 SCOPE AND APPLICABILITY

This Standard states requirements for a Level 1 PRA of internal and external hazards while at-power for the evaluation of core damage frequency (CDF). In addition, this Standard states requirements for a limited Level 2 PRA sufficient to evaluate large early release frequency (LERF). The only hazards explicitly excluded from the scope are accidents resulting from purposeful human-induced security threats (e.g., sabotage, terrorism). These requirements are written for operating LWR power plants (i.e., plants with designs and features similar to the plants operating when this Standard was published). They may be used for LWR plants under design or construction or for advanced LWRs, but revised or additional requirements may be needed.

1-1.2.1 Treatment of Hazard Groups

This Standard states specific requirements for the following hazard groups:

(a) Internal Events (Part 2)
(b) Internal Floods (Part 3)
(c) Internal Fires (Part 4)
(d) Seismic Events (Part 5)
(e) High Winds (Part 7)
(f) External Floods (Part 8)
(g) Other Hazards (Part 9)

Many of the technical requirements in Part 2 are fundamental requirements for performing a PRA for any hazard group and are therefore relevant to Part 3, Part 4, Part 5, Part 6 (for external hazard screening), Part 7, Part 8, and Part 9 of this Standard. They are included by reference in those requirements that address the development of the plant response to the damage states created by the hazard groups addressed in Part 3, Part 4, Part 5, Part 6, Part 7, Part 8, and Part 9. Their specific allocation to Part 2 is partially a historical artifact of the way this PRA Standard was developed, with the at-power internal-events (including internal floods) requirements being developed first, and those of the remaining hazard groups being developed later. However, it is also a reflection of the fact that a fundamental understanding of the plant response to a reasonably complete set of initiating events (as defined in Section 1-2.2) provides the foundation for modeling the impact of various hazards on the plant. Thus, even though Part 2 is given a title associated with the internal-events hazard group, it is understood that the requirements in this Part are applicable to all the hazard groups within the scope of the PRA.

(The text presented in **blue font** in this Standard comprise hyperlinks to enable efficient access to referenced sections and elements, requirements, notes, references, etc.)

1-1.2.2 Hazards and Initiating Events

In using this Standard, it is necessary to understand the relationship among "hazard group," "hazard," "hazard event," and "initiating event," which are defined in Section 1-2.2.

In general, there is a range of hazard events associated with any given hazard, and, for analysis purposes, the range can be divided into bins characterized by their severity. Hazard events of different severity can result in different initiating events.

Consider the internal-events hazard group, as this group provides the fundamental understanding of plant response. As noted above, this hazard group includes several hazards, such as transients and loss of coolant accidents (LOCAs), which can be considered as generic hazards.

For transients, different transient events, such as reactor trip and loss of feedwater, can be identified in terms of the different demands they place on critical safety functions; these demands characterize the events' severity.

For LOCAs, the LOCA events applicable to the plant design might be the large LOCA, medium LOCA, small LOCA, and so forth. The small LOCA leading to plant trip on low pressure or low level is a specific binning within the range of the generic type of hazard associated with LOCAs.

Because the internal-events hazard group serves as the fundamental basis for the plant model, the terms "hazard events" and "initiating events" are synonymous, and this structure forms the primary consideration for the remaining hazard groups.

For the remaining hazard groups, the terms "hazard event" and "initiating event" are not synonymous. Rather, a hazard event is identified as the cause of an initiating event by virtue of the effect it has on the plant. The assessment of the effect on the plant defines the reason for the plant trip as well as any additional failures and provides the starting point for the analysis of the plant response. Therefore, in keeping with the definition of "initiating event," for the occurrence of a given hazard event, the initiating event (or events, as more than one outcome may be possible) is (are) a perturbation of the steady-state operation of the plant that challenges plant control and safety systems whose failure could potentially lead to core damage.

For example, consider the earthquake hazard group, which involves only one hazard, that is, earthquakes are the hazard and also the hazard group. This hazard (earthquakes) can be defined in terms of a range of seismic (hazard) events (e.g., 0.1g, 0.3g, 0.5g, >0.75g) and their associated spectral shapes and time histories. The assessment of the potential initiating events resulting from each hazard event is made based on an assessment of the impact of the seismic hazard event on the plant. So, for example, for a 0.1g seismic event, the assessment may be that the likelihood of any physical damage resulting in an automatic trip is very small; for 0.3g and 0.5g seismic events, the most likely effect may be damage to the switchyard or the transmission system, with a very small likelihood of any seismic induced failures that could result in any other initiating event; and for a >0.75g seismic event, in addition to a loss of off-site power (LOOP), there may be a high likelihood of failure of vessel or piping anchorage causing an induced LOCA. Based on such an assessment

(a) A manual scram may be the only credible initiating event for the 0.1g seismic hazard event.

(b) A LOOP would be assumed to be a hazard, whereas a grid-related LOOP would be an initiating event for the 0.3g and 0.5g seismic hazard events.

(c) In addition to a grid-related LOOP, a LOCA would be included as a hazard, whereas a small break LOCA would be an initiating event for very large (>0.75g) earthquakes.

When multiple initiating events are possible, each will have a conditional probability of occurrence which, when combined with the hazard event frequency, provides the corresponding initiating event frequency.

It is even possible that a hazard event would not result in an initiating event (i.e., there would be no perturbation of the plant operation). For example, a plant may automatically trip (initiating event), may be manually tripped (initiating event), or may continue (no initiating event) to operate through a hurricane event. These examples highlight why the distinction between "hazard event" and "initiating event" is important and must be maintained.

1-1.3 STRUCTURE FOR PRA REQUIREMENTS

1-1.3.1 PRA Technical Elements

The technical requirements for the PRA model are organized by their respective PRA technical elements. The PRA technical elements define the scope of the analysis for each Part of this Standard. This Standard specifies technical requirements for the PRA technical elements listed in Table 1-1.3-1.

1-1.3.2 High-Level Requirements

A set of objectives and High Level Requirements (HLRs) is provided for each PRA technical element in the Technical Requirements section of each respective Part of this Standard. The HLRs set forth the minimum requirements for a technically acceptable baseline PRA, independent of a PRA application. All HLRs are written by using "shall." The HLRs are defined in general terms and present the overarching context for the derivation of more detailed Supporting Requirements (SRs). The general terms used for HLRs represent not only the diversity of approaches that have been used to develop the existing PRAs but also the need to accommodate future technological innovations.

1-1.3.3 Supporting Requirements

A set of SRs is stated for each HLR (that is included for each PRA technical element) in the Technical Requirements section of each respective Part of this Standard. All SRs are written by using "action verbs" rather than "shall." The meaning of each action verb used in this Standard is stated in Nonmandatory Appendix (NMA) 1-A.

This Standard is intended for a wide range of PRA applications that require a corresponding range of PRA capabilities. PRA applications vary with respect to which risk metrics are employed, which decision criteria are used, the extent of reliance on the PRA results in supporting a decision, and the degree of resolution required for the factors that determine the risk significance of the subject of the decision. In developing the different portions of the PRA model, it is recognized that not every item (e.g., system model) will require the same level of detail, the same degree of plant specificity, or the same degree of realism.

Although the capabilities required for each portion of the PRA to support a PRA application fall on a continuum, two levels are defined and labeled Capability Category I (CC-I) and Capability Category II (CC-II), so that requirements can be developed and presented in a manageable way. Table 1-1.3-2 describes, for three principal attributes of PRA, the bases for defining the Capability Category. This table was used to develop the SRs for each HLR.

The delineation of the Capability Categories within the SRs is generally that the degree of scope and level of detail, the degree of plant specificity, and the degree of realism (i.e., the depth of the analysis) increase from CC-I to CC-II. As the Capability Category increases, the depth of the analysis required also increases. In other cases, increasing the depth of analysis may result in a decrease in the risk, such as when a conservative assumption is refined to be more realistic (e.g., changing from conservative success criteria to more realistic success criteria).

The boundary between these Capability Categories can be defined in only a general sense. When a comparison is made between the capabilities of any given PRA and the SRs of this Standard, it is expected that the capabilities of a PRA's elements or portions of the PRA within each of the elements will not necessarily all fall within the same Capability Category, but rather will be distributed among both Capability Categories.

There may be PRA technical elements, or portions of the PRA within the elements, that fail to meet the SRs for either of these Capability Categories. CC-I requirements should result in a model that is capable of identifying the most risk-significant CDF/LERF accident sequences at a functional or systemic level. CC-II will provide a realistic assessment of CDF/LERF. Furthermore, the SRs have been written so that, within a Capability Category, the interfaces between portions of the PRA are consistent (e.g., requirements for event trees are consistent with the definition of initiating event groups).

When a specific PRA application is undertaken, judgment is needed to determine which Capability Category is needed for each portion of the PRA and, thus, which SRs apply to the PRA applications.

For each SR, the minimum requirements necessary to meet CC-I and CC-II are defined. Some SRs apply to only one Capability Category and some extend across both Capability Categories. When an SR spans both Capability Categories, it applies equally to each Capability Category. When necessary, the differentiation between Capability Categories is made in other associated SRs.

The Technical Requirements section of each respective Part of this Standard also specifies the required documentation to ensure traceability of the analysis.

The SRs specify what to do rather than how to do it, and, in that sense, specific methods for satisfying the requirements are not prescribed. Nevertheless, certain established methods were contemplated during the development of these requirements. Alternative methods and approaches or newly developed methods for meeting the requirements of this Standard may be used if they provide results that are equivalent or superior to the methods usually used and if they meet the HLRs and SRs presented in this Standard. Requirements for newly developed methods are provided in Section 1-7. The requirements for the documentation of any particular method used are established in documentation HLRs for each technical element of each Part, and requirements for peer review are described in Section 1-6. In addition, any example in the SR body or any NMA or note is not to be considered the only way to address a supporting requirement.

1-1.4 APPLICABILITY OF PRA TECHNICAL ELEMENTS

The use of a PRA and the Capability Categories that are required to be met for each of the PRA technical elements will differ among PRA applications. Section 1-3 describes the activities to determine whether a PRA has the capability to support a specific PRA application of risk-informed decision-making (RIDM). Two different PRA Capability Categories are described in Section 1-1.3. PRA capabilities are evaluated for each associated SR, rather than by specifying a Capability Category for specific parts or the whole PRA.

1-1.5 PRA CONFIGURATION CONTROL PROGRAM

Section 1-5 states requirements for configuration control of a PRA (i.e., maintaining and upgrading a plant-specific PRA) such that the PRA represents the as-built, as-operated facility to a degree sufficient to support the PRA application for which it is used.

Table 1-1.3-1 PRA Technical Elements Addressed by This Standard

Hazard Type	Hazard Group	PRA Technical Elements
Internal Hazards	Internal Events	Initiating Events Analysis (IE) Accident Sequence Analysis (AS) Success Criteria (SC) Systems Analysis (SY) Human Reliability Analysis (HR) Data Analysis (DA) Quantification (QU) LERF Analysis (LE)
	Internal Floods	Internal Flood Plant Partitioning (IFPP) Internal Flood Source Identification and Characterization (IFSO) Internal Flood Scenario Development (IFSN) Internal Flood-Initiating Event Analysis (IFEV) Internal Flood PRA Plant Response Model (IFPR) Internal Flood Human Reliability Analysis (IFHR) Internal Flood Risk Characterization (IFQU)
	Internal Fires	Internal Fire Plant Boundary Definition and Partitioning (PP) Internal Fire-Initiating Events and Equipment Selection (ES) Internal Fire Cable Selection and Location (CS) Internal Fire Qualitative Screening (QLS) Internal Fire Plant Response Model (PRM) Internal Fire Scenario Selection and Analysis (FSS) Internal Fire Ignition Frequency (IGN) Internal Fire Circuit Failure Analysis (CF) Internal Fire Human Reliability Analysis (FHR) Internal Fire Risk Quantification (FQ)
External Hazards	Seismic Events	Seismic Hazard Analysis (SHA) Seismic Fragility Analysis (SFR) Seismic Plant Response Analysis (SPR)
	High Winds	Wind Hazard Analysis (WHA) Wind Fragility Analysis (WFR) Wind Plant Response Analysis (WPR)
	External Floods	External Flood Hazard Analysis (XFHA) External Flood Fragility Analysis (XFFR) External Flood Plant Response Analysis (XFPR)
Other Hazards (internal or external)	See Note (1)	"X" Hazard Analysis (XHA) "X" Hazard Fragility Analysis (XFR) "X" Hazard Plant Response Analysis (XPR) "X" Screening and Conservative Analysis (EXT)

NOTE:
(1) For any other hazard group "X," the approach for performing a PRA for the hazard group shall meet requirements HLR-XHA, HLR-XFR, and HLR-XPR in Part 9. Each hazard for which a unique approach is developed shall constitute its own hazard group. Hazards that share a common approach, methods, and data shall be analyzed as a single hazard group. Examples of such hazard groups include biological events and external fires.

Table 1-1.3-2 Bases for PRA Capability Categories

Attributes of PRA	Capability Category I	Capability Category II
1. Scope and Level of Detail: The degree to which the scope and level of detail of the plant design, operation, and maintenance are modeled	Resolution and specificity are sufficient to identify the relative importance of the contributors at the hazard group, initiating event group, and functional or systemic accident sequence level, including associated human failure events (HFEs) [Notes (1) and (2)].	Resolution and specificity are sufficient to identify the relative importance of the risk-significant contributors at the hazard group, initiating event group, functional and systemic accident sequence, and basic event level, including associated HFEs, and for hazards other than internal events, at the hazard scenario level. [Notes (1) and (2)].
2. Plant Specificity: The degree to which plant-specific information is incorporated in modeling the as-built, as-operated plant	Use of generic data/models is acceptable except for the need to account for unique design and operational features of the plant that have bearing on the assessment of CDF/LERF.	Plant-specific data/models are used for the risk-significant contributors to the extent feasible
3. Realism: The degree to which realism is incorporated in modeling the expected response of the plant	Departures from realism may have a moderate impact on the conclusions and risk insights as supported by state of the practice [Note (3)].	Departures from realism will have a small impact on the conclusions and risk insights as supported by state of the practice [Note (3)].

NOTES:
(1) The hazard scenarios are the events in the PRA logic model that capture the frequency of the initiating hazard and represent the impact of the hazard on the plant, taking into account those protective measures that are in place to prevent damage from the hazard. The plant specificity and realism attributes will be used to ensure that the hazard scenarios are evaluated in a manner consistent with the other contributors, subject to the limitations imposed by the differences in treatments of each hazard.
(2) The definitions for CC-I and CC-II are not meant to imply that the scope and level of detail include identification of all components and human actions but rather that they include only those needed for the function of the system being modeled to the extent that function is important to assessing plant risk as defined in the context of this Standard.
(3) Differentiation between moderate and small is determined by the extent to which the impact on the conclusions and risk insights could affect a decision under consideration. This differentiation recognizes that the PRA would generally not be the sole input to a decision. A moderate impact implies that the impact (of the departure from realism) is of sufficient size that it is likely that a decision could be affected; a small impact implies that it is unlikely that a decision could be affected.

1-1.6 PEER REVIEW REQUIREMENTS

Section 1-6 states the general requirements for a peer review to determine if the methods and its implementation in the PRA meet the requirements of the Technical Requirements section of each respective Part of this Standard.

1-1.7 ADDRESSING MULTIPLE HAZARD GROUPS

The technical requirements to determine the technical adequacy of a PRA for different hazard groups to support PRA applications are presented in Part 2, Part 3, Part 4, Part 5, Part 7, Part 8, and Part 9. The approaches to modeling the plant damage resulting from different hazard groups vary in terms of the degree of realism and the level of detail achievable. For example, there are uncertainties that are unique to the modeling of the different hazards and their effect on the plant, and the assumptions made in dealing with these uncertainties can lead to varying degrees of conservatism in the estimates of risk. Furthermore, because the analyses can be resource intensive, it is normal to use screening approaches to limit the number of detailed scenarios to be evaluated and the number of mitigating systems credited while still achieving an acceptable evaluation of risk.

For many PRA applications, it is necessary to include the combined impact on risk from those hazard groups for which it cannot be demonstrated that the impact on the decision being made is not risk insignificant. This combination can be done by using a single model that combines the PRA models for the different hazard groups or by combining the results from separate models. In either case, when combining the results from the different hazard groups, it is essential to account for the differences in levels of conservatism and levels of detail so that the conclusions drawn from the results are not overly biased or distorted. To support this objective, this Standard is structured so that requirements for the analysis of the PRA results, including identification of risk-significant contributors, identification and characterization of sources of uncertainty, and identification of assumptions, are included in each Part separately.

In some cases, the requirements for developing a PRA model in Part 3, Part 4, Part 5, Part 7, Part 8, and Part 9 refer back to the requirements of Part 2. The requirements of Part 2 should be applied to the extent needed, given the context of the modeling of each hazard group. In each Part, many of the requirements that differentiate between Capability Categories, either directly or by incorporating the requirements of Part 2, do so on the basis of the analysis of risk-significant contributors and risk-significant accident sequences/cutsets for the hazard group being addressed. Because, as discussed above, there are differences in the way the PRA models for each specific hazard group are developed, the requirements are best analyzed separately in a self-contained manner for each hazard. In other words, these requirements are identified with respect to the CDF and LERF for each hazard group separately. While there is a need in some PRA applications to assess the risk significance with respect to the total CDF or LERF, this assessment has to be done with a full understanding of the differences in conservatism and level of detail introduced by the modeling approaches for the different hazard groups, as well as within each hazard group.

Additionally, from a practical standpoint, PRA models are generally developed on a hazard group basis [e.g., a fire PRA, a seismic PRA, a high wind PRA (HWPRA)]. While they may be integrated into a single model with multiple hazards, the development is done on a hazard group basis. In CC-II, this Standard strives to ensure that the more risk-significant contributors to each hazard group are understood and analyzed with an equivalent level of resolution across applicable SRs, plant specificity, and realism, so as to not skew the results for that hazard group. The definitions in Section 1-2.2 also acknowledge that there may be cases where the proposed quantitative assessment process is inappropriate (e.g., the hazard group risk is very low or bounding methods are used).

To summarize, the definitions in Section 1-2.2 that use the term "risk significant" simply help to define how much realism is necessary to meet CC-II of some SRs. They are *not* intended to be definitions of what is risk significant in a particular PRA application. Indeed, in the context of a specific PRA application, they may be either too loose or too restrictive, depending on what is being evaluated. In the context of this Standard, the decisions on applying these definitions and/or defining what is risk significant for a decision would be addressed in the Risk Assessment Application Process (see Section 1-3).

1-1.8 SCREENING CRITERIA

This Section discusses the underlying rationale for the criteria to be used in this Standard when screening out items from consideration when constructing the PRA model. Screening is an inherent part of constructing a PRA model. It is a tool used to simplify the PRA model while retaining important contributors to risk. As such, the underlying screening process is to ensure that items that are screened out do not impact the results and insights provided by the PRA model.

Hazards, initiating events, accident sequences, plant areas, plant structures, systems failure modes, or components failure modes and HFEs can each be subjected to the screening process as the PRA model is constructed. Table 1-1.8-1 specifies the general criteria (both quantitative and qualitative) that shall be used in considering whether any of the above items can be screened out from consideration in the construction of the PRA. These general criteria are referenced, as needed, in the individual Parts and should be applied only as directed from the SRs in the Part. Because of significant design differences and associated risk profiles, the general criteria in Table 1-1.8-1 are not applicable to advanced LWRs. In addition to these general criteria, the individual Parts may also include supplemental Part-specific criteria that should be employed in completing the screening activity.

Note that although a hazard (or hazard group) may be screened out from being developed per the requirement of the applicable Part of this Standard, the screened out hazard (or hazard group) may still need to be considered in the RIDM for a specific application.

In the context of hazards that are associated with a range of severities (rather than a single discrete event), the "initiating event frequency" refers to the frequency with which a specified site "impact threshold" is exceeded (i.e., exceedance frequency). Impact threshold is the hazard severity at which a plant transient may occur. The screening criteria to be applied to each item for each hazard are specified in Part 2, Part 3, Part 4, Part 5, Part 7, Part 8, and Part 9 SRs. Screening is permitted only within the hazard under consideration. These screening criteria are to be used only when specified in an SR. Use of alternative screening criteria to those in this Section may be allowed with documented justification if the referencing SR specifically states that alternative screening criteria are permitted. Otherwise, the criteria in Table 1-1.8-1 are to be used as written.

1-1.9 UNDERSTANDING RISK SIGNIFICANCE

One of the main outcomes of a state-of-practice PRA is the possibility to identify risk-significant contributors based on quantitative criteria (i.e., an item under consideration that contributes above a certain percentage to the overall risk).

The requirements provided in this Standard are aimed at ensuring that the analysis maintains an appropriate level of completeness such that even at CC-I it is possible to identify risk-significant contributors.

Depending on the intended application of the PRA, risk-significant elements can then be used to inform design and/or plant operation improvements or to inform appropriate focus on maintenance or regulatory activities. Risk-significant items are prime targets for analysis refinements aimed at enhancing the realism of the associated insights.

Generally, identifying the elements of the model (e.g., cutsets, sequences, scenarios) that contribute 95% of the hazard risk is sufficient to capture the significant contributors. Assuring that these contributors are represented in a realistic way and allowing the remaining 5% contribution to be evaluated in a simplified, less realistic fashion will not affect decision-making. Beyond consideration of the elements that represent combinations of basic events, an individual basic event could be sufficiently important by itself to the risk profile. A practical approach to address this condition can be an assessment of the relative importance of the individual basic event via thresholds such as an individual contribution of 1% to total hazard risk (i.e., CDF or LERF), a Fussell-Vesely (FV) importance of 0.005, or a Risk Achievement Worth (RAW) of 2.

In line with the above, Table 1-1.9-1 specifies the quantitative criteria generally to be used in determining risk significance for the various modeling items (contributors). If these quantitative criteria are not used, justification for any alternative quantitative criteria shall be documented. The documentation shall describe how the alternative quantitative criteria meet the intent of the criteria in Table 1-1.9-1. These alternative quantitative criteria shall be peer reviewed for their appropriateness and ability to adequately determine risk significance such that the integrity of the PRA model is maintained. Once the potential risk-significant

Table 1-1.8-1 Generic Screening Criteria

Index No. SCR	Screening Metric	Screening Criteria
SCR-1	Hazard or hazard groups	Mean CDF less than 1.0E-6 per reactor-year and mean LERF less than 1.0E-7 per reactor-year, as estimated using a demonstrably conservative analysis for each hazard or hazard group
SCR-2	Relative (individual contributors)	*(a)* Less than 1% contribution to the aggregate probability or frequency of the items subject to screening, as defined in the referencing SR and the total contribution of the screened out items not exceeding 5% of the group of items subject to screening as defined in the referencing SR, or *(b)* contributing <1.0E-8 per reactor-year to CDF and <1.0E-9 per reactor-year to LERF and the total contribution of the screened out items not exceeding 5% of the group of items subject to screening as defined in the referencing SR
SCR-3	Deterministic	Demonstratively conservative assessments that the element screened out does not impact the plant or is subsumed into a more frequent or more impactful event

contributors are identified along with the specific technical requirements, the next major step is to apply the needed refinements into the modeling inputs.

Risk significance is often used in the iteration process to build a PRA model. Thus, initial simplifying assumptions that may impact multiple portions of the PRA model may need to be reviewed and modified as needed to increase the PRA model realism. This type of iteration is performed until the PRA model represents a realistic risk profile of the plant to the extent practical according to the state of practice. Consequently, the focus should be on increasing the realism of those elements of the PRA that have the potential to significantly impact the model results.

The determination of risk significance is extremely important to the ultimate level of effort required to finalize the PRA. Therefore, the numerical thresholds used to identify risk-significant items should be considered in the context of the resolution of the quantification process and the relative risk contribution of the various hazards included. In some cases, it will be necessary to consider different numerical thresholds or to demonstrate that distortions in importance measures will not alter the risk insights and risk ranking of the PRA model.

Table 1-1.9-1 describes how risk significance is determined for the different types of modeling items (contributors).

Table 1-1.9-1 Risk Significance Determination

Item	Criteria for Risk Significance Determination [Note (1)]
Risk-significant accident progression sequence	One of the set of accident sequences contributing to LERF resulting from the analysis of a specific hazard group that, when rank-ordered by decreasing frequency, sum to a specified percentage of the LERF or that individually contribute more than a specified percentage of LERF for that hazard group. The summed percentage of 95% and the individual percentage of 1% of the applicable hazard group are generally used.
Risk-significant accident sequence	One of the set of accident sequences resulting from the analysis of a specific hazard group, defined at the functional or systematic level, that, when rank-ordered by decreasing frequency, sum to a specified percentage of the CDF for that hazard group or that individually contribute more than a specified percentage of CDF. The summed percentage of 95% and the individual percentage of 1% of the applicable hazard group are generally used.
Risk-significant basic event	A basic event that contributes significantly to the computed risks for a specific hazard group. This contribution generally includes any basic event that has an FV importance greater than 0.005 or a RAW importance greater than 2.
Risk-significant containment challenge	A containment challenge that results in a containment failure mode that is represented in a risk-significant accident progression sequence.
Risk-significant contributor	A basic event; structure, system, or component (SSC); piece of equipment; HFE; scenario; and so on that contributes to a significant sequence or cutset or contributes significantly to the computed risks for a significant sequence or cutset-specific hazard group.
Risk-significant cutset	A cutset is one element of an accident sequence resulting from the analysis of a specific hazard group that, when rank-ordered by decreasing frequency, sums to a specified percentage of the CDF (or LERF) for that hazard group or that individually contributes more than a specified percentage of CDF (or LERF). The summed percentage of 95% and the individual percentage of 1% of the applicable hazard group are generally used. Cutset significance may also be measured relative to overall CDF (or LERF) or relative to an individual accident sequence CDF (or LERF) of the applicable hazard group.

NOTE:
(1) If these criteria are not used, justification for any alternative criteria shall be documented. The documentation shall describe how the alternative criteria meet the intent of the stated criteria in this table. These alternative criteria shall be peer reviewed for their appropriateness and ability to adequately determine risk significance such that the integrity of the PRA model is maintained.

Section 1-2
Acronyms and Definitions

The following definitions are provided to ensure a uniform understanding of acronyms and terms as they are specifically used in this Standard.

1-2.1 ACRONYMS

AC: alternating current

ADS: automatic depressurization system

AEF: Annual Exceedance Frequency

ANS: American Nuclear Society

AOPs: abnormal operating procedures

APC: atmospheric pressure change

ASCE: American Society of Civil Engineers

ASTM: American Society for Testing and Materials

ATWS: anticipated transient without scram

BOP: balance of plant

BWR: boiling water reactor

CC-I and *CC-II:* Capability Categories I and II

CCDP: conditional core damage probability

CCF: common cause failure

CDF: core damage frequency

CLERP: conditional large early release probability

DC: direct current

DOE: US Department of Energy

DW: drywell

ECCS: emergency core cooling system

EOPs: emergency operating procedures

EPRI: Electric Power Research Institute

FMEA: failure modes and effects analysis

FSAR: Final Safety Analysis Report

FV: Fussell-Vesely importance measure

GMC: ground motion characterization

GMPE: Ground Motion Prediction Equation

GRS: Ground Response Spectra

HEP: human error probability

HFE: human failure event

HLR: High Level Requirement

HPME: high pressure melt ejection

HRA: human reliability analysis

HROI: Hazard Range of Interest

HVAC: heating, ventilation, and air conditioning

HW: high wind

HWEL: High Wind Equipment List

HWPRA: high wind PRA

HWTL: high-wind target list

IE: initiating event

IFPRA: internal flooding PRA

IPE: individual plant examination

ISLOCA: interfacing systems loss of coolant accident

ISRS: in-structure response spectra

LERF: large early release frequency

LIP: local intense precipitation

LLNL: Lawrence Livermore National Laboratory

LOCA: loss of coolant accident

LOOP: loss of off-site power (also referred to as "LOSP")

LWR: light water reactor

MCC: motor control center

MCR: main control room

MSO: multiple spurious operation

NEI: Nuclear Energy Institute

NMA: Nonmandatory Appendix

NFPA: National Fire Protection Association

NPP: nuclear power plant

NPSH: net positive suction head

NRC: Nuclear Regulatory Commission

NSSS: nuclear steam supply system

NUREG: NRC report

PAU: physical analysis unit

PDS: plant damage state

PFHA: probabilistic flood hazard analysis

PGA: peak ground acceleration

PRA: probabilistic risk assessment

PSHA: probabilistic seismic hazard analysis

PWHA: probabilistic wind hazard analysis

PWR: pressurized water reactor

RAW: Risk Achievement Worth

RCS: reactor coolant system

RE: Reference Earthquake

RES: Office of Nuclear Regulatory Research (of the NRC)

RIDM: risk-informed decision-making

RPV: reactor pressure vessel

Sa: spectral acceleration

SBO: station blackout

SCDF: seismic core damage frequency

SEL: seismic equipment list

SGTR: steam generator tube rupture

SLERF: seismic large early release frequency

SLCS: standby liquid control system

SPRA: seismic probabilistic risk assessment

SR: Supporting Requirement

SSC(s): structure(s), system(s), and component(s)

SSHAC: Senior Seismic Hazard Analysis Committee

SSI: soil-structure interaction

THERP: Technique for Human Error Rate Prediction (see NUREG/CR-1278 [1-1])

TS: Technical Specifications

UHS: uniform hazard response spectrum

V/H: vertical-to-horizontal (ratio)

XFEL: external flood equipment list

XFPRA: external flood PRA

1-2.2 DEFINITIONS

accepted method: a method that the regulatory body has used or accepted for the specific risk-informed application for which it is proposed.

accident class: a grouping of severe accidents with similar characteristics (e.g., accidents initiated by a transient with a loss of decay heat removal, LOCAs, station blackout accidents, and containment bypass accidents).

accident progression sequence: a unique combination of events that clearly delineate the chronological and physical progression of core damage, containment response, and fission product release to the environment.

accident sequence: a representation in terms of an initiating event followed by a sequence of failures or successes of events (e.g., system, function, or operator performance) that can lead to undesired consequences, with a specified end state (e.g., core damage or large early release).

accident sequence analysis: the process to determine the combinations of initiating events, safety functions, and system failures and successes that may lead to core damage or large early release.

adversely affect: to impact plant equipment items leading to equipment failure (e.g., in the context of a fire PRA, a fire that includes spurious operation of devices).

aleatory uncertainty: the uncertainty inherent in a nondeterministic (stochastic, random) phenomenon. Aleatory uncertainty is represented by modeling the phenomenon in terms of a probabilistic model. In principle, aleatory uncertainty cannot be reduced by the accumulation of more data or additional information (aleatory uncertainty is sometimes called "randomness").

as-built, as-operated: a conceptual term that represents the degree to which the PRA matches the current plant design, plant procedures, and plant performance data, relative to a specific point in time. (NOTE: At the design certification stage, the plant is neither built nor operated. For these situations, the intent of the PRA model is to represent the "as-designed, as-to-be-built, and as-to-be-operated" plant.)

associated effects: characteristics of the flood event that are not captured solely by flood elevation (height). Associated effects include factors such as wind waves and runup effects; hydrostatic loading; hydrodynamic loading, including debris and water velocities; effects caused by sediment deposition and erosion; clogging due to debris; concurrent site conditions, including adverse weather conditions; and groundwater ingress.

assumption: a judgment that is made in the development of the PRA model either for modeling convenience or because of lack of information or state of knowledge. An assumption is a source of model uncertainty:

(a) An example of assumption used for modeling convenience is limiting the number of individual modeled components under the assumption that the consequence of any individual combination of components is the same.

(b) An example of assumption made for lack of information is assuming component failure due to failure of heating, ventilation, and air conditioning (HVAC) in the absence of detailed room heat-up calculations.

atmospheric pressure change: atmospheric pressure change loads result from the variation in the atmospheric pressure field as a vortex moves over a structure. Atmospheric pressure change loads are considered in tornado design and depend on the amount of venting or leakage of the structure as a translating tornado interacts with the structure.

at-power: those plant operating states characterized by the reactor being critical and producing power, with automatic actuation of critical safety systems not blocked and with essential support systems aligned in their normal power operation configuration.

availability: the complement of unavailability.

baseline PRA: a PRA that has been developed consistent with the Technical Requirements of this Standard independent of an application.

basic event: an event in a fault-tree model that requires no further development because the appropriate limit of resolution has been reached.

cable: referring solely to "electric cables," a construction comprising one or more insulated electrical conductors (generally copper or aluminum). A cable may or may not have other physical features such as an outer protective jacket, a protective armor (e.g., spiral wound or braided), shield wraps, and/or an uninsulated ground conductor or drain wire. Cables are used to connect points in a common electrical circuit and may be used to transmit power, control signals, indications, or instrument signals.

cable failure mode: the behavior of an electrical cable on fire-induced failure that may include intracable shorting, intercable shorting, and/or shorts between a conductor and an external ground (see also *hot short*).

capability category: see Table 1-1.3-2.

circuit failure mode: the manner in which a conductor fault is manifested in the circuit. Circuit failure modes include loss of motive power, loss of control, loss of or false indication, open circuit conditions (e.g., a blown fuse or open circuit protective device), and spurious operation.

cliff edge effect: an instance of a sudden large variation in plant conditions in response to a small variation in an input (e.g., change in flood height, grid perturbation based on voltage or frequency exceeding a breaker trip set point).

coexistent hazard: hazard that is a secondary hazard to and/or concurrent with another hazard.

common cause failure: a failure of two or more components during a short period of time as a result of a single shared cause.

community distribution: for any specific expert judgment, the distribution of expert judgments of the entire relevant (informed) technical community of experts knowledgeable about the given issue.

component: an item in a nuclear power plant, such as a vessel, pump, valve, or circuit breaker.

composite variability: the composite variability includes the randomness uncertainty (β_R) and the modeling and data uncertainty (β_U). The logarithmic standard deviation of composite variability, β_C, is expressed as $(\beta_R{}^2 + \beta_U{}^2)^{1/2}$.

concurrent hazard: a hazard that occurs simultaneously with the occurrence of another hazard as a result of a common cause [e.g., high winds (HWs) concurrent with storm surge event caused by a hurricane or a moderate wind event concurrent with a large rainfall event].

conservative: use of information (e.g., assumptions) such that the assessed outcome is meant to be less favorable than the expected outcome.

containment bypass: a direct or indirect flow path that may allow the release of radioactive material directly to the environment bypassing the containment.

containment challenge: severe accident conditions (e.g., plant thermal hydraulic conditions or phenomena) that may result in compromising containment integrity. These conditions or phenomena can be compared with containment capability to determine whether a containment failure mode results.

containment failure: loss of integrity of the containment pressure boundary from a core damage accident that results in unacceptable leakage of radio nuclides to the environment.

containment failure mode: the manner in which a containment radionuclide release pathway is created. It encompasses both those structural failures of containment induced by containment challenges when they exceed containment capability and the failure modes of containment induced by HFEs, isolation failures, or bypass events such as interfacing systems LOCA (ISLOCA).

containment performance: a measure of the response of a nuclear plant containment to severe accident conditions.

consensus method/model: a method or model that the regulatory body has used or accepted for the specific risk-informed application for which it is proposed.

core damage: uncovery and heat-up of the reactor core to the point at which prolonged oxidation and severe fuel damage are anticipated and involving enough of the core, if released, to result in off-site public health effects.

core damage frequency: expected number of core damage events per unit of time.

damage criteria: those characteristics of the fire-induced environmental effects that will be taken as indicative of the fire-induced failure of a damage target or set of damage targets.

damage target: see target.

damage threshold: the values corresponding to the damage criteria that will be taken as indicative of the onset of fire-induced failure of a damage target or set of damage targets.

demonstrably conservative: use of input information or assumptions that provides high confidence that the assessed outcome is as conservative as it is portrayed to be.

dependency: requirement that is external to an item and upon which its function depends and that is associated with dependent events that are determined by, influenced by, or correlated to other events or occurrences.

distribution system: piping, raceway, duct, or tubing that carries or conducts fluids, electricity, or signals from one point to another.

electrical overcurrent protective device: an active or passive device designed to prevent current flow from exceeding a predetermined level by breaking the circuit when the predetermined level is exceeded (e.g., fuse or circuit breaker).

end state: the set of conditions at the end of an accident sequence that characterizes the impact of the sequence on the plant or the environment. In most PRAs, end states typically include success states (i.e., those states with negligible impact), plant damage states for Level 1 sequences, and release categories for LERF sequences.

epistemic uncertainty: the uncertainty attributable to incomplete knowledge about a phenomenon that affects our ability to model it. Epistemic uncertainty is represented by ranges of values for parameters, a range of viable models, the level of model detail, multiple expert interpretations, and statistical confidence. In principle, epistemic uncertainty can be reduced by the accumulation of additional information. This definition is used in the context of seismic hazard and fragility.

equipment: a term used to broadly cover the various components in a nuclear power plant. Equipment includes electrical and mechanical components (e.g., pumps, control and power switches, integrated circuit components, valves, motors, fans) and instrumentation and indication components (e.g., status indicator lights, meters, strip chart recorders, sensors). "Equipment," as used in this Standard, *excludes* electrical cables.

equipment qualification: the generation and maintenance of data and documentation to demonstrate that equipment is capable of operating under the conditions of a qualification test or under test and analysis.

evaluator expert: an expert who is capable of evaluating the relative credibility of multiple alternative hypotheses and who is expected to evaluate all potential hypotheses and bases of inputs from proponents and resource experts to provide both evaluator input and other experts' representation of the community distribution.

event tree: a logic diagram that begins with an initiating event or condition and progresses through a series of branches that represent expected system or operator performance that either succeeds or fails and arrives at either a successful or failed end state.

expert elicitation: a formal, highly structured, and documented process whereby expert judgments, usually of multiple experts, are obtained.

expert judgment: information provided by a technical expert, in the expert's area of expertise, based on opinion or on an interpretation based on reasoning that includes evaluations of theories, models, or experiments.

exposed structural steel: structural steel elements that are not protected by a passive fire-barrier feature (e.g., fire-retardant coating) with a minimum fire-resistance rating of 1 hr.

external flood hazard mechanism (flooding mechanism): the physical processes by which a natural or manmade flood-forcing phenomenon can lead to overflow or accumulation of water on or near a site.

external hazard: a hazard originating outside a nuclear power plant that directly or indirectly causes an initiating event and may cause safety system failures or operator errors that may lead to core damage or large early release. Hazards such as earthquakes, tornadoes, and floods from sources outside the plant and fires from sources outside the plant are considered external hazards. (See also *internal event*.) By historical convention, LOOP not caused by another external hazard is considered to be an internal event.

facilitator/integrator: a single entity (individual, team, company, etc.) that is responsible for aggregating the judgments and community distributions of a panel of experts to develop the composite distribution of the informed technical community (herein called "the community distribution").

failure mechanism: any of the processes that result in failure modes, including chemical, electrical, mechanical, physical, thermal, and human error.

failure mode: a specific functional manifestation of a failure (i.e., the means by which an observer can determine that a failure has occurred) by precluding the successful operation of a piece of equipment, a component, or a system (e.g., fails to start, fails to run, leaks). (NOTE: In the context of fire PRA, *spurious operation* is also considered a failure mode above and beyond failures that preclude successful operation.)

failure modes and effects analysis: a process for identifying failure modes of specific components and evaluating their effects on other components, subsystems, and systems.

failure probability: the likelihood that an SSC will fail to operate on demand or fail to operate for a specific mission time.

failure rate: expected number of failures per unit time, evaluated, for example, by the ratio of the number of failures in a population of components to the total time observed for that population.

fault tree: a deductive logic diagram that depicts how a particular undesired event can occur as a logical combination of other undesired events.

figure of merit: the quantitative value, obtained from a PRA, used to evaluate the results of a PRA application (e.g., CDF or LERF).

fire analysis tool: as used in this Standard, "fire analysis tool" is broadly defined as any method used to estimate or calculate one or more physical fire effects (e.g., temperature, heat flux, time to failure of a damage target, rate of flame spread over a fuel package, heat release rate for a burning material, smoke density) based on a predefined set of input parameter values, as defined by the fire scenario being analyzed. Fire analysis tools include, but are not limited to, computerized compartment fire models, closed-form analytical formulations, empirical correlations such as those provided in a handbook, and lookup tables that relate input parameters to a predicted output.

fire area: a portion of a building or plant that is separated from other areas by rated fire barriers adequate for the fire hazard. (NOTE: A rated fire barrier is a fire barrier with a fire-resistance rating.)

fire barrier: a continuous vertical or horizontal construction assembly designed and constructed to limit the spread of heat and fire and to restrict the movement of smoke.

fire compartment:[1] a subdivision of a building or plant that is a well-defined enclosed room, not necessarily bounded by rated fire barriers. A fire compartment generally falls within a fire area and is bounded by noncombustible barriers where heat and products of combustion from a fire within the enclosure will be substantially confined. Boundaries of a fire compartment may have open equipment hatches, stairways, doorways, or unsealed penetrations. This term is defined specifically for fire risk analysis and maps plant fire areas and/or zones, defined by the plant and based on fire protection systems design and/or operations considerations, into compartments defined by fire damage potential. For example, the control room or certain areas within the turbine building may be defined as a fire compartment.

fire-induced initiating event: that initiating event assigned to occur in the fire PRA plant response model for a given fire scenario.

fire modeling: as used in this Standard, "fire modeling" refers to the process of exercising a fire analysis tool including the specification and verification of input parameter values, performance of any required supporting calculations, actual application of the fire analysis tool itself, and the interpretation of the fire analysis tool outputs and results.

fire protection program: the integrated effort involving equipment, procedures, and personnel used in carrying out all activities of fire protection. It includes system and facility design, fire prevention, fire detection, annunciation, confinement, suppression, administrative controls, fire brigade organization, inspection and maintenance, training, quality assurance, and testing.

fire-resistance rating: the time, in minutes or hours, that materials or assemblies have withstood a fire exposure as established in accordance with an approved test procedure appropriate for the structure, building material, or component under consideration.

fire scenario: a set of elements that describes a fire event. The elements usually include a physical analysis unit, a source fire location and characteristics, detection and suppression features to be included, damage targets, and intervening combustibles.

fire scenario selection: the process of defining a fire scenario to be analyzed in the fire PRA that will represent the behavior and consequences of fires involving one or more fire ignition sources. Fire scenario selection includes the identification of a fire ignition source (or set of fire ignition sources); secondary combustibles and fire spread paths; fire damage targets, detection and suppression systems and features to be credited; and other factors that will influence the extent and timing of fire damage.

fire suppression system: generally refers to permanently installed fire protection systems provided for the express purpose of suppressing fires. Fire suppression systems may be either automatically or manually actuated. However, once activated, the system should perform its design function with little or no manual intervention.

fire wrap: a localized protective covering designed to protect cables, cable raceways, or other equipment from fire-induced damage. Fire wraps generally provide protection against thermal damage.

flood area: an area within a plant that is defined for the purpose of performing a flood assessment PRA. Flood areas are normally defined in terms of one or more of the following: building types; location within a building or the site; and the physical barriers that delay, restrict, or prevent the propagation of floods to adjacent areas. Flood areas refer to areas of buildings or of the site that may be flooded due to internal or external flooding sources.

flood event duration (external flooding): defines the period of time that a flood hazard affects the site. Flood event duration typically begins with conditions being met for entry into a flood procedure or notification of an impending flood and ends when flood waters have receded from the site. It typically includes warning time (if available) and period of inundation and recession.

flood hazard (external flooding): those hydrometeorological, geoseismic, or structural failure phenomena (or combination thereof) that may produce flooding at or near nuclear power plant site.

flood-induced accident sequence: an accident sequence that includes a flood-induced initiating event and the potential for undesired consequences, with a specified end state (e.g., core damage).

flood-induced failure mechanism: the failure mechanism of an SSC induced by a flood. Possible SSC failure mechanisms include, but are not limited to, shorting out of electrical connections, blockage of air intakes, and structural damage from flood loads. In the context of external flooding, flood-induced failure mechanisms may include additional factors such as blockage of sumps (e.g., due to debris) and overtopping of barriers.

flood-induced initiating event: an initiating event that is caused by a flood either directly (e.g., loss of system function caused by diversion of flow associated with the flood) or indirectly (e.g., plant shutdown caused by the loss of function of one or more flood-damaged SSCs). In the context of external flooding, flood-induced initiating events also include initiating events due to damage of SSCs from the floodwaters.

flood initiating area (internal flooding): the area from which the flood originates.

flood propagation path: a physical pathway that would allow the progression of a flood within and among different flood areas. In the context of external flooding,

[1] It is noted that the term "fire compartment" is used in other contexts, such as general fire protection engineering, and that the term's meaning as used here may differ from that implied in an alternative context. However, the term also has a long history of use in fire PRA and is used in this Standard based on that history of common fire PRA practice.

flood propagation paths may begin with floods that originate from a source external to the plant.

flood rate: the flow rate of water or steam across the breach or opening in the pressure boundary of the flood source during the flood event. In the context of external flooding, the flood rate may also include the rate of flow of external flood water into a flood area. Depending on the context, the flood rate may be a time-dependent rate, a maximum rate, or an average rate over the duration of the flood.

flood response SSCs (external flooding): SSCs that may be used to maintain key safety functions during conditions that might occur during an external flood scenario, including SSCs that are indirectly related to maintenance of key safety functions (e.g., barriers that protect SSCs from floodwaters or other related effects).

flood scenario: a description of an event that results in a flood-induced initiating event. The factors included in the definition of a flood scenario are flood area; flood source; flood rate; flood propagation path; impact on plant SSCs; human actions included in flood initiation, mitigation, and termination; and means of detection (sensors, alarms, indications, etc.).

flood source: an inventory of water or steam normally contained within a system, tank, component, reservoir, river, lake, or ocean that provides the potential for flooding-induced failure of SSCs in the event the flood source container or pressure or retention boundary is breached.

flood volume: the total flood volume of water released from the source from flood initiation to termination or to a specific point in time during a flood scenario; unless specified as the localized volume in specific flood areas for scenarios that involve multiple flood areas, flood volume is normally used to calculate the nominal flood height, which is associated with the submergence failure cause. Water-spray volumes are generally different from flood volumes, but spray water may accumulate and contribute to flood volumes.

fragility: fragility of an SSC is the conditional probability of its failure at a given hazard input level. The input could be earthquake motion, wind speed, or flood level. The fragility model used in seismic PRA is known as a double lognormal model with three parameters, which are the median acceleration capacity, the logarithmic standard deviation of the aleatory (randomness) uncertainty in capacity, and the logarithmic standard deviation of the modeling and data uncertainty in the median capacity.

frontline system: a system (safety or nonsafety) that is capable of directly performing one of the accident-mitigating functions (e.g., core or containment cooling, coolant makeup, reactivity control, or reactor vessel pressure control) modeled in the PRA.

Fussell-Vesely: for a specified basic event, FV importance is the fractional contribution to the total of a selected figure of merit for all accident sequences containing that basic event. For PRA quantification methods that include nonminimal cutsets and success probabilities, the FV importance measure is calculated by determining the fractional reduction in the total figure of merit brought about by setting the probability of the basic event to zero.

ground acceleration: acceleration at the ground surface produced by seismic waves, typically expressed in units of *g*, the acceleration of gravity at the Earth's surface.

harsh environment: an abnormal environment (e.g., high or low temperature, humidity, corrosive conditions) expected as a result of postulated accident conditions appropriate for the design basis or beyond design basis accidents.

hazard: a phenomenon that challenges the safe operation of a facility. A hazard is a subset of a hazard group and a superset of hazard events. Hazards in the internal events hazard group include LOCAs and LOOPs. In some cases, a hazard group may consist of only one hazard (e.g., the seismic hazard), in which case the hazard and the hazard group are considered to be synonymous.

hazard analysis: the process to determine an estimate of the expected frequency of exceedance (over some specified time interval) of various levels of some characteristic measure of the intensity of a hazard (e.g., peak ground acceleration to characterize ground shaking from an earthquake). The time period of interest is typically 1 yr, in which case the estimate is called the annual frequency of exceedance.

hazard event: an event brought about by the occurrence of the specified hazard. A hazard event is described in terms of the specific levels of severity of impact that a hazard can have on the plant. For example, an internal flood event would be expressed in terms of the specific flood source and its local impact, such as the resulting water levels in affected plant areas or the extent of the area subjected to spray; a seismic event would be expressed in terms of spectral acceleration and associated spectral shape; a transient event would be expressed in terms of the plant systems affected by the event.

hazard group: a group of hazards that result in similar effects on or challenges to a facility. A hazard group is a subset of a hazard type and a superset of hazards. The hazards in a given hazard group may be assessed using a common approach, methods, and likelihood data for characterizing the effect on the plant. Examples of hazard groups include internal events, internal flood, seismic, and HW. In some cases, a hazard group may only consist of one hazard (e.g., the seismic hazard), in which case the hazard group and the hazard are considered to be synonymous.

hazard type: a hazard type is a superset of hazard groups. Internal hazards include hazard groups such as internal events and internal fire and external hazards include hazard groups such as the seismic hazard and external flooding.

high energy arcing fault: electrical arc that leads to a rapid release of electrical energy in the form of heat, vaporized copper, and mechanical force.

high energy line: a pipe or piping system component is classified as high energy if it contains water or steam at maximum operating temperature exceeding 200°F or maximum operating pressure exceeding 275 psig.

high energy line break: a break or breach in a high energy line.

high-hazard fire source: a fire source that can lead to fires of a particularly severe and challenging nature. High-hazard fire sources would include, but are not limited to, catastrophic failure of an oil-filled transformer, an unconfined release of flammable or combustible liquid, leaks from a pressurized system containing flammable or combustible liquids, and significant releases or leakage of hydrogen or other flammable gases.

high winds: tornadoes, hurricanes (or cyclones or typhoons as they are known outside the United States), extratropical (thunderstorm) winds, and other wind phenomena depending on the site location.

high wind equipment list: the SSCs whose performance may be impaired as a consequence of the HW hazard.

hot short: individual conductors of the same or different cables coming in contact with each other where at least one of the conductors involved in the shorting is energized, resulting in an impressed voltage or current on the circuit being analyzed.

human error: any human action that exceeds some limit of acceptability, including inaction where required, excluding malevolent behavior.

human error probability: a measure of the likelihood that plant personnel will fail to initiate the correct, required, or specified action or response in a given situation or, by commission, performs the wrong action. The HEP is the probability of the HFE.

human failure event: a basic event that represents a failure or unavailability of a component, system, or function that is caused by human inaction or an inappropriate action.

human reliability analysis: a structured approach used to identify potential HFEs and to systematically estimate the probability of those events using data, models, or expert judgment.

human response action: a post-initiator operator action, following a cue or symptom of an event, taken to satisfy the procedural requirements for control of a function or system.

ignition frequency: frequency of fire occurrence generally expressed as fire ignitions per reactor-year.

ignition source: piece of equipment or activity that causes fire.

initiating event: a perturbation to the steady-state operation of the plant that challenges plant control and safety systems whose failure could potentially lead to core damage. An initiating event is defined in terms of the change in plant status that results in a condition requiring a reactor trip (e.g., loss of main feedwater system, small LOCA) or a manual trip prompted by conditions other than those in the normal shutdown procedure when the plant is at-power. An initiating event may result from human causes, equipment failure from causes internal to the plant (e.g., hardware faults, floods, or fires) or external to the plant (e.g., earthquakes or HWs), or combinations thereof.

initiator: see *initiating event*.

insights: information that provides an understanding and explanation of what is and is not important to the analysis.

integrator: a single entity (individual, team, company, etc.) that is ultimately responsible for developing the composite representation of the informed technical community (herein called "the community distribution"). This integration sometimes involves informal methods such as deriving information relevant to an issue from the open literature or through informal discussions with experts and sometimes involves more formal methods.

intensity: a measure of the impact of a hazard.

intercable (as in "intercable conductor-to-conductor short circuit"): electrical interactions (shorting) between the conductors of two (or more) separate electrical cables (see also *intracable*).

interfacing systems LOCA (ISLOCA): a LOCA when a breach occurs in a system that interfaces with the reactor coolant system (RCS), where isolation between the breached system and the RCS fails. An ISLOCA is usually characterized by the overpressurization of a low-pressure system when subjected to RCS pressure and can result in containment bypass.

internal event: a hazard group that encompasses events other than floods or fires that result from or involve mechanical, electrical, structural, or human failures from causes originating within a nuclear power plant or losses of off-site power (except when caused by another hazard) that directly or indirectly cause an initiating event and may cause safety system failures or operator errors that may lead to core damage.

intracable (as in "intracable conductor-to-conductor short circuit"): electrical interactions (shorting) between the conductors of one multiconductor electrical cable (see also *intercable*).

key safety functions: the minimum set of safety functions that must be maintained to prevent core damage and large early release. These include reactivity control, reactor pressure control, reactor coolant inventory control, decay heat removal, and containment integrity in appropriate combinations to prevent core damage and large early release.

large early release: a large release occurring before the effective implementation of off-site emergency response and protective actions and there is the potential for early health effects.

large early release frequency (LERF): expected number of large early releases per unit of time.

large release: the release of airborne fission products to the environment such that there are significant off-site impacts. Large release and significant off-site impacts may be defined in terms of quantities of fission products released to the environment, status of fission product barriers and scrubbing, or dose levels at specific distances from the release, depending on the specific analysis objectives and regulatory requirements.

LERF analysis: evaluation of containment response to severe accident challenges and quantification of the mechanisms, amounts, and probabilities of subsequent radioactive material releases from the containment.

level 1 analysis: identification and quantification of the sequences of events leading to the onset of core damage.

level of detail: the degree to which (i.e., amount of) information is discretized and included in the model or analysis.

licensee-controlled area: areas of the plant site that are directly controlled by the nuclear power plant licensee.

local intense precipitation: a locally heavy rainfall event that is typically defined by specifying three parameters: rainfall depth, rainfall duration, and spatial extent (area). LIP is typically associated small-scale events over geographic areas on the order of 1 to 10 square-miles and by an assumption that the rainfall rate is aerially uniform, although the rainfall rate (intensity) typically varies over the rainfall event. Although total duration of the LIP-caused flooding event depends on the scenario and site-specific characteristics (e.g., site drainage, susceptibility to ponding of water), LIP events are typically associated with a short duration (e.g., 1 to 6 hrs) of intense rainfall. These intense rainfall events may be imbedded within longer rainfall events and (depending on site drainage characteristics) may affect a site for longer durations. In the context of this Standard, LIP is defined generically and is not limited to stylized deterministic events, such as the so-called 1-hr, 1-square-mile, probable maximum precipitation event.

lower bound wind speed, V_L: the lower bound wind speed used to define the wind speed threshold for HWs in an HWPRA. Wind speeds less than V_L are assumed to be unable to produce damage to risk-significant SSCs at the plant.

low-ruggedness relays: electromechanical relays that may chatter at low levels of earthquake excitation or on impact, causing malfunction of electrical circuits.

master logic diagram: summary fault tree constructed to guide the identification and grouping of initiating events and their associated sequences to ensure completeness.

may: used to state an option to be implemented at the user's discretion.

method: an analytical approach used to satisfy a supporting requirement or collection thereof in the PRA. An analytical approach is generally a compilation of the analyses, tools, assumptions, and data used to develop a model.

missile fragility: fragility of SSCs for a given missile impact.

mission time: the time period that a system or component is required to operate in order to successfully perform its function.

model: a qualitative and/or quantitative representation that is constructed to portray the inherent characteristics and properties of what is being represented (e.g., a system, component or human performance, theory or phenomenon). A model may be in the form, for example, of a structure, schematic, or equation. Method(s) are used to construct the model under consideration.

multicompartment fire scenario: a fire scenario involving targets in a room or fire compartment other than or in addition to the one where the fire was originated.

multiple spurious operations: concurrent spurious operations of two or more equipment items.

mutually exclusive events: a set of events where the occurrence of any one precludes the simultaneous occurrence of any remaining events in the set.

newly developed method: a method used in a PRA that has either been developed separately from a state-of-practice method or is one that involves a fundamental change to a state-of-practice method. A newly developed method is not a state-of practice or a consensus method.

nonsuppression probability: probability of failing to suppress a fire before target damage occurs.

operating time: total time during which components or systems are performing their designed function.

parameter uncertainty: the uncertainty in the value of an input parameter that represents the degree of belief in the range of values the input parameter may assume. Examples of parameter uncertainty include, but are not limited to, probability distributions or confidence intervals (i.e., a range of probability values within which the actual value of the input parameter is expected to reside) for an input parameter such as an initiating event frequency or a component failure probability.

passive flood protection feature: a flood protection feature that does not require the change of state of a component in order for it to perform as intended. Examples include dikes, berms, sumps, drains, basins, yard drainage systems, walls, floors, structures, penetration seals, and external berms/barriers that are under licensee control.

passive SSC: an SSC that performs one or more safety functions either fully or partially via passive means (i.e., relying on natural physical processes such as natural convection, thermal conduction, radiation, gravity, or pressure differentials, or depending on the integrity of a pressure boundary or structural component). Examples include piping systems that are used to maintain an inventory of fluid and deliver flow along a fluid path, and structural supports for SSCs.

peak ground acceleration: maximum value of acceleration displayed on an accelerogram; the largest ground acceleration produced by an earthquake at a site.

performance shaping factor: a factor that influences HEPs as considered in a PRA's Human Reliability Analysis and includes such items as level of training, quality/availability of procedural guidance, time available to perform an action, and so on.

physical analysis units: the spatial subdivisions of the plant on which an internal flood or internal fire PRA is based. The physical analysis units are generally defined in terms of flood or fire areas and/or flood or fire compartments under the plant partitioning technical element.

plant: a general term used to refer to a nuclear power facility (e.g., "plant" could be used to refer to a single unit or multiunit site).

plant boundary: defined by the user based on the scope of plant structures.

plant damage state: group of accident sequence end states that have similar characteristics with respect to accident progression and containment or engineered safety feature operability.

plant response model: a logic model, including the event trees and fault trees and the various SSC and human failures, that is used to delineate and evaluate the CDF/LERF accident sequences conditional on the occurrence of a hazard event (or hazard group).

plant-specific data: data consisting of observed sample data from the plant being analyzed.

point estimate: estimate of a parameter in the form of a single number.

post-initiator human failure events: HFEs that represent the impact of human errors committed during response to abnormal plant conditions.

power block elevation (for purposes of external-flood PRA): the as-built elevation of the ground surface in the area of the site power block. There may be more than one elevation of relevance to the external flood PRA; for example, different elevations may be relevant to different locations around the site.

PRA application: a documented analysis based in part or whole on a plant-specific PRA that is used to assist in decision-making with regard to the design, licensing, procurement, construction, operation, or maintenance of a nuclear power plant.

PRA maintenance: a change in the PRA that does not meet the definition of PRA upgrade.

PRA upgrade: a change in the PRA that results in the applicability of one or more SRs or Capability Categories that were not previously included within the PRA (e.g., performing qualitative screening in Part 4 when this HLR was previously not applicable or the addition of a new hazard model), an implementation of a PRA method in a different context, or the incorporation of a method not previously used.

pre-initiator human failure events: HFEs that represent the impact of human errors committed during actions performed prior to the initiation of an accident (e.g., during maintenance or the use of calibration procedures).

primary hazard: those hazards that are not the consequence of other preceding hazards.

prior distribution (priors): in Bayesian analysis, the expression of an analyst's prior belief about the value of a parameter prior to obtaining sample data.

probabilistic risk assessment: a quantitative assessment of the risk including all technical elements for modeled hazards associated with plant operation and maintenance that is measured in terms of frequency of occurrence of risk metrics, such as core damage or a radioactive material release and its effects on the health of the public (also referred to as a probabilistic safety analysis).

probability of exceedance (as used in seismic hazard analysis): the probability that a specified level of ground motion for at least one earthquake will be exceeded at a site or in a region during a specified exposure time.

raceway: an enclosed channel of metal or nonmetallic materials designed expressly for holding wires, cables, or bus bars, with additional functions as permitted by code. Raceways include, but are not limited to, rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, liquid-tight flexible conduit, flexible metallic tubing, flexible metal conduit, electrical nonmetallic tubing, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways, wireways, and busways.

randomness (as used in seismic fragility analysis): the variability in seismic capacity arising from the randomness of the earthquake characteristics for the same acceleration and to the structural response parameters that relate to these characteristics.

rare event: one that might be expected to occur only a few times throughout the world nuclear industry over many years (e.g., <1.0E-4 per reactor-yr).

reactor critical year: a calendar year in the operating life of one reactor, assuming that the reactor operated continuously for a year.

reactor-operating-state-year: an equivalent calendar year of operation in a particular plant operating state.

reactor-year: a calendar year in the operating life of one reactor, regardless of power level.

realism: an accurate representation (to the extent practical) of the expected response of the as-built, as-operated plant.

recovery: restoration of a function lost as a result of a failed SSC by overcoming or compensating for its failure. It is generally modeled by using HRA techniques.

reference wind speed: refers to a set of specified wind parameters associated with the use of wind speed as the independent hazard and fragility parameter in HWPRAs. The parameters required to define the reference wind (based on wind speed) include averaging time, surface roughness, height above ground, and direction.

reliability: the complement of unreliability.

repair: restoration of a failed SSC by correcting the cause of failure and returning the failed SSC to its modeled functionality; generally modeled by using actuarial data.

repair time: the period from identification of a component failure until it is returned to service.

resource expert: a technical expert with knowledge of a particular technical area of a PRA.

response: a reaction to a cue for action in initiating or recovering a desired function.

response spectrum: a curve calculated from an earthquake accelerogram that gives the value of peak response in terms of acceleration, velocity, or displacement of a damped linear oscillator (with a given damping ratio) as a function of its period (or frequency).

risk: probability and consequences of an event, as expressed by the "risk triplet" that is the answer to the following three questions:

(a) What can go wrong?
(b) How likely is it?
(c) What are the consequences if it occurs?

risk achievement worth (RAW) importance measure: for a specified basic event, risk achievement worth importance represents the increase in a selected figure of merit when an SSC is assumed to be unable to perform its function due to testing, maintenance, or failure. It is the ratio or interval of the figure of merit, evaluated with the SSC's basic event probability set to one, to the base case figure of merit.

risk-relevant consequences: the fire-induced failure of any risk-relevant target, or the fire-induced creation of environmental conditions that may complicate or preclude credited postfire operator actions.

risk-relevant damage targets: any equipment item or cable whose operation is credited in the fire PRA plant response model or whose operation may be required to support a credited postfire operator action.

risk-relevant ignition source: any ignition source included in the fire PRA fire scenario definitions that could cause a fire that might induce a plant initiating event or adversely affect one or more damage targets.

risk-significant: see definitions in Table 1-1.9-1.

safe stable state: a plant condition, following an initiating event, in which RCS conditions are controllable at or near desired values.

safety function: function that must be performed to control the sources of energy in the plant and radiation hazards.

safety systems: those systems that are designed to prevent or mitigate a design-basis accident.

screening: a process that eliminates items from further consideration based on their negligible contribution to the probability of an accident or its consequences, or from further analysis of a specific issue.

screening criteria: the values and conditions used to determine whether an item is a negligible contributor to the probability of an accident sequence or its consequences.

secondary combustible: combustible or flammable materials that are not a part of the fire ignition source that may be ignited if there is fire spread beyond the fire ignition source.

secondary hazard: used in connection with, and in contrast to, a primary hazard. It is an additional hazard effect that is induced by the primary hazard.

seismic margin: seismic margin is expressed in terms of the earthquake motion level that compromises plant safety, specifically leading to severe core damage. The margin concept can also be extended to any particular structure, function, system, equipment item, or component for which "compromising safety" means sufficient loss of safety function to contribute to core damage either independently or in combination with other failures.

seismic source: a general term referring to both seismogenic sources and capable tectonic sources. A seismogenic source is a portion of the Earth assumed to have a uniform earthquake potential (same expected maximum earthquake and recurrence frequency), distinct from the seismicity of the surrounding regions. A capable tectonic source is a tectonic structure that can generate both vibratory ground motion and tectonic surface deformation such as faulting or folding at or near the Earth's surface. In a probabilistic seismic hazard analysis, all seismic sources in the site region with a potential to contribute to the frequency of ground motions (i.e., the hazard) are included.

seismic spatial interaction: an interaction that could cause an equipment item to fail to perform its intended safety function. It is the physical interaction of a structure, pipe, distribution system, or other equipment item with a nearby item of safety equipment caused by relative motions from an earthquake. The interactions of concern are

(a) proximity effects
(b) structural failure and falling
(c) flexibility of attached lines and cables

severe accident: an accident that involves extensive core damage and fission product release into the reactor vessel and containment, with potential release to the environment.

severity factor: severity factor is the probability that fire ignition would include certain specific conditions that influence its rate of growth, level of energy emanated, and duration (time to self-extinguishment) to levels at which target damage is generated.

shall: used to state a mandatory requirement.

should: used to state a recommendation.

skill of the craft: actions that one can assume that trained staff would be able to readily perform without written procedures (e.g., simple tasks such as turning a switch or opening a manual valve as opposed to a series of sequential actions or set of actions that need to be coordinated).

source of model uncertainty: the uncertainty associated with the variability of an input of interest where the input of interest can be derived or calculated via different modeling approaches, where the selected approach is not clearly more correct or does not represent a consensus of the technical community, and where the choice of modeling approach is known to have an impact on the PRA model (e.g., introduction of a new basic event, changes to basic event probabilities, change in success criterion, or introduction of a new initiating event).

spectral acceleration: given as a function of period or frequency and damping ratio (typically 5%), spectral acceleration is equal to the peak relative displacement of a linear oscillator of frequency, f, attached to the ground, times the quantity $(2\pi f)^2$. It is expressed in gravitational acceleration (g) or centimeters per second squared (cm/s^2).

split fraction: a unitless quantity that represents the conditional (on preceding events) probability of choosing one direction rather than the other through a branch point of an event tree.

spurious operation: the undesired operation of equipment resulting from a fire that could affect the capability to achieve and maintain safe shutdown.

state of practice: those practices that are widely accepted and implemented throughout the nuclear industry, that have been shown to be technically acceptable in documented analyses or engineering assessments, and that have been shown to be acceptable in the context of the intended application.

state-of-knowledge correlation: the correlation that arises between sample values when performing uncertainty analysis for cutsets consisting of basic events by using a sampling approach (e.g., the Monte Carlo method). When the state of knowledge correlation is included, it results, for each sample, in the same value being used for all basic event probabilities to which the same data apply.

station blackout: complete loss of alternating current electric power to the essential and nonessential switchgear buses in a nuclear power plant.

statistical model: a model in which a modeling parameter or behavior is analyzed as a random variable with specified statistical characteristics.

straight winds: wind hazards that do not have a powerful rotational wind component. For example, straight winds include thunderstorm and extratropical cyclone winds.

success criteria: criteria for establishing the minimum number or combinations of systems or components required to operate, operator actions, or minimum levels of performance per component during a specific period of time to ensure that the safety functions are satisfied.

support system: a system that provides a support function (e.g., electric power, control power, or cooling) for one or more other systems.

system failure: loss of the ability of a system to perform a modeled function.

target: may refer to a HW, a fire damage target, and/or an ignition target. A fire damage target is any item whose function can be adversely affected by the modeled fire. Typically, a fire damage target is a cable or equipment item that belongs to the fire PRA cable or equipment list and that is included in event trees and fault trees for fire risk estimation. An ignition target would be any flammable or combustible material to which fire might spread.

target set: a group of damage targets that will be assumed to suffer fire-induced damage based on the same damage criteria and damage threshold in any given fire scenario. The collection of target sets associated with a fire scenario often represents a subset of the damage targets present in the fire compartment but may also encompass all risk-relevant damage targets in a single physical analysis unit or a collection of damage targets in multiple physical analysis units. This definition implies that all members of any single target set will be assumed to fail when the first member of the target set fails (i.e., "damage based on the same damage criteria and damage threshold"). Progressive or time-dependent states of fire damage may be represented through the definition of multiple target sets for a single fire scenario (e.g., cables in raceways directly above a fire source versus cables in raceways remote from the fire source). The level of detail associated with target set definition will generally parallel the level of detail employed in fire scenario selection and analysis (e.g., screening level analysis versus detailed analysis).

time available: the time period from the presentation of a cue for human action or equipment response to the time of adverse consequences if no action is taken.

top event: undesired state of a system in the fault tree model (e.g., the failure of the system to accomplish its function) that is the starting point (at the top) of the fault tree.

truncation limit: the numerical cutoff value of probability or frequency below which results are not retained in the quantitative PRA model or used in subsequent calculations (such limits can apply to accident sequences/cutsets, system level cutsets, and sequence/cutset database retention).

unavailability: the probability that a system or component is not capable of supporting its function including, but not limited to, the time it is disabled for test or maintenance. Total system unavailability includes unreliability.

uncertainty analysis: the process of identifying and characterizing the sources of uncertainty in the analysis and evaluating their impact on the PRA results and developing a quantitative measure to the extent practical.

uncertainty: a representation of the confidence in the information or state of knowledge about the parameter values and models used in constructing the PRA.

uniform hazard response spectrum: a plot of a ground response parameter (e.g., spectral acceleration or spectral velocity) that has an equal likelihood of exceedance at different frequencies.

unreliability: the probability that a system or component will not perform its specified function under given conditions on demand or for a prescribed time.

walkdown: physical inspection of relevant areas of the nuclear power plant site (and its surroundings, as necessary) to obtain or confirm information such that the PRA model represents the as-built, as-operated plant.

walkthrough: step-by-step consideration of a procedure along with, if possible, visits to relevant locations and demonstration of actions.

wind-driven rain: wind-driven rain is rain that has a horizontal velocity component from wind. Wind-driven rain is an effect that may require consideration when HWs damage a building, exposing interior equipment to water damage from rain water, drips, and splash.

wind effects: the physical loading effects that can result from HW hazards, including wind pressure and atmospheric pressure change, wind-generated missiles, structural interactions, wind-driven rain, and correlated hazard effects.

Section 1-3
PRA Scope and Capabilities in Support of Risk-Informed Applications

1-3.1 PURPOSE

This Section describes needed activities to establish the capability of a PRA to support a particular risk-informed application. For this Section, the term "PRA" (or "PRA model") can refer to either an integrated model that includes all relevant hazard groups or multiple PRA models that address one or more hazard groups. For a specific application, PRA capabilities are evaluated in terms of Capability Categories for individual SRs rather than by specifying a single Capability Category for the whole PRA. Depending on the application, the required PRA capabilities may vary over and within different Parts of this Standard. The process is intended to be used with PRAs that have had a peer review that meets the requirements of the Peer Review Section of each respective Part of this Standard.

1-3.2 IDENTIFICATION OF APPLICATION AND DETERMINATION OF CAPABILITY CATEGORIES

1-3.2.1 Identification of Application

Define the application by

(a) evaluating the plant design or operational change being assessed

(b) identifying the SSCs and plant activities affected by the change including the cause-effect relationship between the plant design or operational change and the PRA model

(c) identifying the hazard groups, PRA model scope, and PRA risk metrics that are needed to assess the change

EPRI 3002014783 [1-2] and RG 1.174 [1-3] provide guidance for the above activities.

1-3.2.2 Determination of Capability Categories

Other Parts of this Standard state SRs for the PRA Capability Categories whose attributes are described in Section 1-1.3.

For many of the SRs, the distinction between Capability Categories is based on the treatment of significant contributors. Definitions in this Standard containing the word "significance" or "significant" are generally written from the perspective of a specific hazard group. It is important to recognize that, for applications whose risk stems from more than one hazard group, these definitions should be generalized to apply to the sum of risks from all contributing hazard groups. "Significance" should also be treated differently for those SRs that refer to SRs in other hazard groups.

For the application, determine the relative importance of each portion of the PRA for each hazard group needed to support the application. This determination dictates which Capability Category is needed for each SR for each portion of the PRA to support the application. To determine these capabilities, an evaluation of the application should be performed to assess the role of the PRA in supporting that application, including determining the relative importance of SRs to the application; identifying the portions of the hazard group PRA relevant to the application; and for each relevant portion, determining the Capability Category for each SR needed to support the application. When performing this evaluation, the following application attributes shall be considered:

(a) the role of the PRA in the application and extent of reliance of the decision on the PRA results

(b) the risk metrics to be used to support the application and associated decision criteria

(c) the significance of the risk contribution from the hazard group to the decision

(d) the degree to which bounding or conservative methods for the PRA or in a given portion of the PRA would lead to inappropriately influencing the decisions made in the application and the approach(es) to accounting for this in the decision-making process

(e) the degree of accuracy and evaluation of uncertainties and sensitivities required of the PRA results

(f) the degree of confidence in the results that is required to support the decision

(g) the extent to which the decisions made in the application will impact the plant design basis

The Capability Categories and the bases for their determination shall be documented.

Section 1-4
Requirements for Use of Expert Judgment

1-4.1 PURPOSE

This Section states general requirements for use of expert judgment.

1-4.2 USE OF EXPERT JUDGMENT

This section states requirements for the use of expert judgment outside of the PRA analysis team to resolve a specific technical issue.

Guidance from NUREG/CR-6372 [1-4] and NUREG-1563 [1-5] may be used to meet the requirements in this paragraph. Other approaches, or a mix of these, may also be used.

1-4.2.1 Objective of Using Expert Judgment

The PRA analysis team shall explicitly and clearly define the objective of the information that is being sought through the use of outside expert judgment and shall explain this objective and the intended use of the information to the expert(s).

1-4.2.2 Identification of the Technical Issue

The PRA analysis team shall explicitly and clearly define the specific technical issue to be addressed by the expert(s).

1-4.2.3 Determination of the Need for Outside Expert Judgment

The PRA analysis team may elect to resolve a technical issue by using their own expert judgment or the judgment of others within their organization.

The PRA analysis team shall use outside experts when the needed expertise on the given technical issue is not available within the analysis team or within the team's organization. The PRA analysis team should use outside experts, even when such expertise is available inside, if there is a need to obtain broader perspectives for any of the following or related reasons:

(a) Complex experimental data exist that the analysts know have been interpreted differently by different outside experts.

(b) More than one conceptual model exists for interpreting the technical issue, and judgment is needed as to the applicability of the different models.

(c) Judgments are required to assess whether bounding assumptions or calculations are appropriately conservative.

(d) Uncertainties are large and risk significant, and judgments of outside technical experts are useful in illuminating the specific issue.

1-4.2.4 Identification of Expert Judgment Process

The PRA analysis team shall determine

(a) the degree of importance and the level of complexity of the issue

(b) whether the process will use a single entity (individual, team, company, etc.) that will act as an evaluator and integrator and will be responsible for developing the community distribution or a panel of expert evaluators and a facilitator/integrator

The facilitator/integrator shall be responsible for aggregating the judgments and community distributions of the panel of experts so as to develop the composite distribution of the informed technical community.

1-4.2.5 Identification and Selection of Evaluator Experts

The PRA analysis team shall identify one or more experts capable of evaluating the relative credibility of multiple alternative hypotheses to explain the available information. These experts shall evaluate potential hypotheses and bases of inputs from the literature, and from proponents and resource experts, and shall provide

(a) their own input

(b) their representation of the community distribution

1-4.2.6 Identification and Selection of Technical Issue Experts

If needed, the PRA analysis team shall also identify other technical issue experts such as

(a) experts who advocate particular hypotheses or technical positions (e.g., an individual who evaluates data and develops a particular hypothesis to explain the data)

(b) technical experts with knowledge of a particular technical subject of relevance to the issue

1-4.2.7 Responsibility for the Expert Judgment

The PRA analysis team shall assign responsibility for the resulting judgments to an integrator or the experts. Each individual expert shall accept responsibility for their individual judgments and interpretations.

Section 1-5
PRA Configuration Control Program

1-5.1 INTRODUCTION

This Section states requirements for a configuration control program to support the use of a PRA in risk-informed decisions for nuclear power plants. The HLRs and SRs for this PRA Configuration Control (CC) Program are contained in Table 1-5.3-1, Table 1-5.3-2, Table 1-5.3-3, Table 1-5.3-4, Table 1-5.3-5, and Table 1-5.3-6. As these are administrative requirements, there is no gradation across Capability Categories. A discussion of the requirements is presented below.

1-5.2 OBJECTIVE

The objective of the configuration control program is to ensure that when a PRA is to be used in risk-informed decisions, it represents the as-built, as-operated plant at the time of the decision. Furthermore, it ensures that any updates of the PRA are consistent with the technical requirements of this Standard.

Table 1-5.3-1 High Level Requirements for PRA Configuration Control (CC) Program

Designator	Requirement
HLR-CC-A	The PRA Configuration Control Program shall include a process for monitoring changes to the plant design, operation, PRA technology, and industry experience and for collecting updated performance information that could result in changes to PRA inputs.
HLR-CC-B	The PRA Configuration Control Program shall include a process that maintains and upgrades the PRA to be consistent with the as-built, as-operated plant.
HLR-CC-C	The PRA Configuration Control Program shall consider the cumulative impact of pending changes in the performance of risk applications.
HLR-CC-D	The PRA Configuration Control Program shall include a process that maintains configuration control of computer codes and associated files used to support PRA.
HLR-CC-E	The PRA Configuration Control Program and its implementation shall be documented.

Table 1-5.3-2 Supporting Requirements for HLR-CC-A

The PRA Configuration Control Program shall include a process for monitoring changes to the plant design, operation, PRA technology, and industry experience and for collecting updated performance information that could result in changes to PRA inputs (HLR-CC-A).

Index No. CC-A	Requirements
CC-A1	IMPLEMENT a process to track plant changes, PRA technology, and related industry equipment performance/operational experience focused on collecting the necessary information to update PRA inputs.
CC-A2	In the information collected, INCLUDE the plant-specific changes in design, operation, and maintenance of the plant that impact, for example, the following: *(a)* operating procedures and practices (e.g., operations orders) *(b)* emergency and abnormal operating procedures *(c)* design configuration *(d)* initiating event frequencies *(e)* system or subsystem unavailabilities *(f)* component failure rates *(g)* maintenance policies *(h)* operator training *(i)* technical specifications *(j)* engineering calculations *(k)* emergency plan *(l)* accident management programs
CC-A3	In the information collected, INCLUDE changes to external facilities, sources of external hazards, or internal or external features that impact how external hazards may affect the plant. Such information may include, but is not limited to *(a)* changes in dam operating procedures that impact water release strategies *(b)* regional changes that impact riverine flooding hazard analysis *(c)* capabilities of external response centers if such centers are credited in the PRA
CC-A4	In the information collected, INCLUDE changes in industry experience that could impact *(a)* estimation of initiating event frequencies *(b)* generic system or subsystem unavailabilities *(c)* generic component failure rates *(d)* initiating events
CC-A5	In the information collected, INCLUDE changes to the PRA technology that could change the results of the PRA model.

Table 1-5.3-3 Supporting Requirements for HLR-CC-B

The PRA Configuration Control Program shall include a process that maintains and upgrades the PRA to be consistent with the as-built, as-operated plant (HLR-CC-B).

Index No. CC-B	Requirements
CC-B1	EVALUATE changes in PRA inputs or new information identified pursuant to HLR CC-A to determine whether such information warrants PRA maintenance or PRA upgrade. INCLUDE in the PRA changes identified per HLR-CC-A.
CC-B2	INCLUDE in the PRA those maintenance or upgrade changes implemented per HLR-CC-A that would impact risk-significant insights.
CC-B3	PERFORM a peer review of portions of the PRA that are affected by a PRA upgrade in accordance with the applicable requirements specified in Section 1-6. The scope may be limited within a technical element to only the SRs that are germane to a specific PRA upgrade.
CC-B4	ENSURE that changes to the PRA due to PRA maintenance or upgrade meet the requirements of the Technical Requirements section of each respective Part of this Standard.
CC-B5	REVIEW maintenance or upgrade changes made to the PRA by using a utility-approved process.

Table 1-5.3-4 Supporting Requirements for HLR-CC-C

The PRA Configuration Control Program shall consider the cumulative impact of pending changes in the performance of risk applications (HLR-CC-C).

Index No. CC-C	Requirements
CC-C1	IDENTIFY plant changes that have been identified to have a potential impact on PRA.
CC-C2	IDENTIFY known industry issues or events and PRA technology changes that may have an impact on the PRA model.

Table 1-5.3-5 Supporting Requirements for HLR-CC-D

The PRA Configuration Control Program shall include a process that maintains configuration control of computer codes used to support and perform PRA analyses (HLR-CC-D).

Index No. CC-D	Requirements
CC-D1	ENSURE that the computer codes and associated files used to support and to quantify the PRA are controlled to ensure consistent, reproducible results.

Table 1-5.3-6 Supporting Requirements for HLR-CC-E

The PRA Configuration Control Program and its implementation shall be documented (HLR-CC-E).

Index No. CC-E	Requirements
CC-E1	DOCUMENT the Configuration Control Program and the performance of the above elements in a manner adequate to demonstrate that the PRA is being maintained consistently with the as-built, as-operated plant. The documentation typically includes *(a)* a description of the process used to monitor PRA inputs and collect new information *(b)* evidence that the aforementioned process is active *(c)* descriptions of proposed and implemented changes *(d)* a description of changes in a PRA due to each PRA upgrade or PRA maintenance *(e)* a record of the performance and results of the appropriate PRA reviews (consistent with the requirements of Section 1-6.6) *(f)* a record of the process and results used to address the cumulative impact of pending changes *(g)* a description of the process used to maintain software configuration control *(h)* a record of the process and results used to evaluate changes on previously implemented risk-informed decisions
CC-E2	DOCUMENT the bases for the changes made to the PRA model.

Section 1-6
Peer Review

1-6.1 PURPOSE

This Section states requirements for peer review of the PRA to be used in risk-informed decisions for commercial nuclear power plants. Those portions of PRAs used for PRA applications applying this Standard shall be peer reviewed. The peer review shall assess the PRA to the extent necessary to determine whether the method and its implementation meet the requirements of this Standard. Another purpose of the peer review is to determine the potential gaps in the PRA relative to this Standard's requirements. The peer review need not assess all aspects of the PRA against all requirements in the Technical Requirements section of each respective Part of this Standard but must address all SRs relevant to the scope of the peer review. However, enough aspects of the PRA shall be reviewed for the reviewers to achieve consensus on the adequacy of the assessment of each applicable SR as well as on the methods and their implementation for each PRA technical element.

1-6.1.1 Documentation and Self-Assessment

A prerequisite for performing the peer review is that the PRA has documented the supporting analyses/calculations, including the independent reviews performed, and a self-assessment of the PRA has been conducted to establish the extent to which the PRA meets the requirements of this Standard. The results of the self-assessment process shall be documented.

1-6.1.2 Scope

Peer reviews shall be performed against the requirements in those Parts of this Standard that are applicable to the hazard groups of the PRA that are being used to support risk-informed decisions. It is permissible to conduct a separate and distinct peer review for each relevant hazard or individual elements of a hazard group. This Standard does not require that a single peer review be integrated across all hazard groups of the PRA.

The scope of the peer review may be a "focused–scope" peer review. A focused-scope peer review is a subset of a complete (full-scope) peer review and involves specified SRs. A focused-scope peer reviewed may be requested

(a) to support a specific application that does not involve the complete hazard specific PRA model

(b) to address changes to the PRA model as a result of upgrades, or

(c) to close significant deficiencies from previous peer reviews

When included in the scope of a peer review, a newly developed method shall be reviewed following the dedicated requirements discussed in Section 1-7.

1-6.1.3 Peer Review Process

The review shall be performed using a written process that assesses the requirements of the Technical Requirements section of each respective Part of this Standard and addresses the requirements of the Peer Review Section of each respective Part of this Standard.

The peer review process shall consist of the following elements:

(a) selection of the peer review team

(b) training in the peer review process

(c) an approach to be used by the peer review team for assessing if the PRA meets the supporting requirements of the Technical Requirements section of each respective Part of this Standard

(d) management and resolution of potential differing professional opinions

(e) documentation of the results of the review

1-6.2 PEER REVIEW TEAM COMPOSITION AND PERSONNEL QUALIFICATIONS

1-6.2.1 Collective Team

The peer review team shall consist of personnel whose collective qualifications include

(a) the ability to assess all the PRA technical elements of the Technical Requirements section of each respective Part of this Standard, as applicable, and the interfaces between those elements

(b) the collective knowledge of the plant nuclear steam supply system design, containment design, and plant operation

1-6.2.2 Individual Team Members

The peer review team members individually shall be

(a) knowledgeable of the requirements in this Standard for their area of review

(b) experienced in performing the activities related to the PRA technical elements for which the reviewer is assigned

(c) independent from the team that developed the PRA model or the method being peer reviewed

(d) subject matter experts included to judge the technical adequacy of non-PRA engineering evaluations and to confirm that the applicable envelope defining the limits of the method are identified

(e) prohibited from reviewing work performed by a direct supervisor or work they have directly supervised

1-6.2.3 Specific Review Team Qualifications

The peer reviewer shall also be knowledgeable (by direct experience) of the specific method, code, tool, or approach (e.g., large event-tree linking approach, Modular Accident Analysis Program (MAAP) code, Technique for Human Error Rate Prediction (THERP) method, external hazard analysis, fragility assessment and walkdowns) that was used in the PRA technical element assigned for review. Understanding and competence in the assigned area shall be demonstrated by the range of the individual's experience in the number of different, independent activities performed in the assigned area, as well as the different levels of complexity of these activities:

(a) One member of the peer review team (the technical integrator) shall be familiar with all the PRA technical elements identified in the relevant Part of this Standard under review and shall have demonstrated the capability to integrate these PRA technical elements. When more than one Part is under review, a separate technical integrator may be used for each Part.

(b) The peer review team shall have a team leader to lead the team in the performance of the review. The team leader need not be the technical integrator.

(c) The peer review shall have at least two reviewers dedicated to each reviewed technical element to ensure that consensus can be reached on the technical adequacy of the PRA being reviewed and be conducted over a period of time adequate to ensure that reviewed technical element receives the attention necessary to assess the technical adequacy.

(d) Exceptions to the requirements of this paragraph may be taken based on the nature of the PRA model change. A single-person peer review shall be justified only when the review involves an upgrade of a single element and the reviewer has acceptable qualifications for the technologies involved in the upgrade. All such exceptions shall be documented in accordance with Section 1-6.6 of this Standard. Regardless of any such exceptions, the collective qualification of the review team shall be appropriate to the scope of the peer review

(e) If the peer reviewer is reviewing a newly developed method, the reviewer shall be knowledgeable of the technical subject addressed by the newly developed method. Understanding and competence of the newly developed method shall be demonstrated by the range of the individual's experience in that technical subject. Subject matter experts should be included to judge the technical adequacy of non-PRA engineering evaluations and to confirm that the applicable envelope defining the limits of the method are identified.

1-6.3 REVIEW OF PRA TECHNICAL ELEMENTS TO CONFIRM THE METHODS USED

The peer review team shall use the requirements of this Section. The peer review team shall review the technical requirements of the hazard group to determine if the method and the implementation of the method for each PRA technical element meet the requirements of this Standard. Additional material for those elements may be reviewed depending on the results obtained. The judgment of the reviewer shall be used to determine the specific scope and depth of the review in each PRA technical element and the need for walkdowns.

The results of the appropriate hazard group PRA, including models and assumptions, and the results of each PRA technical element shall be reviewed to determine their reasonableness given the design and operation of the plant (e.g., investigation of cutset or sequence combinations for reasonableness).

Any newly developed method included in the scope of the peer review is reviewed against the requirements of Section 1-7. It is noted that a newly developed method can be peer reviewed within the scope of a plant PRA (i.e., concurrently with its implementation in a plant PRA) or via a dedicated stand-alone peer review. If newly developed methods are peer-reviewed concurrently with the implementations of methods, all specific requirements for the newly developed methods peer review shall be met. If the implementation of the method is peer reviewed in a separate peer review, only the applicable requirements for the scope of the review need to be met.

Even if exceptions to the requirements of Section 1-6.2.3(c) occur, concerning the composition of the peer review team or the duration of the review, all SRs relevant to the scope of the peer review of the PRA are to be reviewed.

The extent of a focused-scope peer review includes all SRs (e.g., not just those for which significant deficiencies were cited), within the HLRs containing SRs with significant deficiencies. New significant deficiencies may be issued even for SRs that did not have previous significant deficiencies, as a focused-scope peer review encompasses all the SRs within an affected HLR.

1-6.4 EXPERT JUDGMENT

The use of expert judgment to implement requirements in this Standard shall be reviewed using the general requirements in Section 1-4.2.

1-6.5 PRA CONFIGURATION CONTROL PROGRAM

The peer review team shall review the process, including implementation, for maintaining or upgrading the

PRA against the configuration control requirements of this Standard. The PRA configuration control program is reviewed against the requirements presented in Section 1-5.

1-6.6 DOCUMENTATION

1-6.6.1 Peer Review Team Documentation

The peer review team's documentation shall demonstrate that the review process appropriately implemented the review requirements. Specifically, the peer review documentation shall include the following:

(a) identification of the version of the PRA reviewed

(b) a statement of the scope of the peer review

(c) the names of the peer review team members

(d) a brief resume for each team member describing the individual's employer, education, PRA training, and PRA and PRA technical element experience and expertise

(e) the elements of the PRA reviewed by each team member

(f) a discussion of the extent to which each PRA technical element was reviewed, including justification for any supporting requirements within the peer review scope that were not reviewed

(g) results of the review identifying any differences between the requirements in the Technical Requirements section of each respective Part of this Standard and Section 1-5 and the method implemented, defined to a sufficient level of detail that will allow the resolution of the differences

(h) identification and significance of exceptions and gaps relative to this Standard's requirements, in sufficient detail to allow the resolution of the gaps that the peer reviewers have determined to be material to the PRA

(i) an assessment of PRA assumptions that the peer reviewers have determined to be material to the PRA

(j) differences or dissenting views among peer reviewers

(k) recommended alternatives for resolution of any differences

(l) an assessment of the Capability Category of the SRs (i.e., identification of what Capability Category is met for the SRs)

(m) peer-review consistent with newly developed method requirements

1-6.6.2 Resolution of Peer Review Team Comments

Resolution of deficiencies against the requirements of this Standard that are identified by the peer review team shall be documented. The resolution of these deficiencies shall describe how each was addressed such that the associated SR can be demonstrated to be met. The documentation shall indicate whether the deficiency is resolved via PRA maintenance or a PRA upgrade. The determination of whether the resolution adequately eliminates the deficiency shall be made by one or more individuals who meet the qualification requirements of Section 1-6.2.2.

Section 1-7 Newly Developed Methods

1-7.1 INTRODUCTION

This Section states requirements for Newly Developed Methods (NM) explicitly developed for use in PRA to support risk-informed decisions for nuclear power plants. The HLRs and SRs for the newly developed methods are contained in Table 1-7.2-1, Table 1-7.2-2, Table 1-7.2-3, Table 1-7.2-4, Table 1-7.2-5, Table 1-7.2-6, and Table 1-7.2-7.

1-7.2 OBJECTIVE

The objectives of the newly developed methods requirements are to ensure that a newly developed method is technically adequate and

(a) has a clearly defined scope and limitations

(b) is based on sound engineering and relevant science

(c) has proper treatment of assumptions and uncertainties

(d) is based on appropriate and well-understood data

(e) produces results that are consistent with expectations

(f) is clearly documented in such a way that knowledgeable personnel can understand it without ambiguity and that there is enough documentation so that it can be peer reviewed.

The objectives above are intended to be applicable to a large spectrum of methods, although it is understood that not all the SRs could be applicable to all methods. In some cases, depending on the method, scope, and purpose, some of the SRs may not be applicable. In addition, the SRs are designed to be able to address a stand-alone method (i.e., independent from its implementation on a specific plant PRA). It is recognized that, in some circumstances, a method can be so plant or site specific (especially in the external hazard domain) that a full review of the method can be performed only within its implementation. In such cases, it is envisioned that some of the Newly Developed Methods SRs could be overlapping with Part-specific SRs (e.g., SRs in Part 8). In such cases, the technical SRs in the appropriate Part may take priority over some Newly Developed Methods SRs.

Table 1-7.2-1 High Level Requirements for Newly Developed Methods (NM)

Designator	Requirement
HLR-NM-A	The purpose and scope of the newly developed method shall be clearly stated.
HLR-NM-B	The newly developed method shall be based on sound engineering and science relevant to its purpose and scope.
HLR-NM-C	The data (note that data can be numeric or non-numeric in nature) shall be relevant to the newly developed method, technically sound, and properly analyzed and applied.
HLR-NM-D	Uncertainties in the newly developed method shall be characterized. Sources of model uncertainties and related assumptions shall be identified.
HLR-NM-E	The results of the newly developed method shall be reproducible, reasonable, and consistent with the assumptions and data, given the purpose and scope of the newly developed method.
HLR-NM-F	The documentation of the newly developed method shall provide traceability of the work and facilitate incorporation of the newly developed method in a PRA model.

Table 1-7.2-2 Supporting Requirements for HLR-NM-A

The purpose and scope of the newly developed method shall be clearly stated (HLR-NM-A).

Index No. NM-A	Requirements
NM-A1	ENSURE that the stated purpose of the newly developed method (i.e., what is being achieved by the newly developed method) is consistent with the scope (established boundary) of the newly developed method.
NM-A2	ENSURE that the applicability and limitations of the newly developed method are consistent with the purpose and scope in SR NM-A1.
NM-A3	Based on the limitations and applicability of the newly developed method, IDENTIFY the areas of the PRA for which the newly developed method is intended to be used and those for which it is specifically not intended (e.g., hazards, technical elements, plant features, SRs impacted by the newly developed method).

Table 1-7.2-3 Supporting Requirements for HLR-NM-B

The newly developed method shall be based on sound engineering and science relevant to its purpose and scope (HLR-NM-B).

Index No. NM-B	Requirements
NM-B1	ESTABLISH the technical bases for the newly developed method by using approaches founded on established mathematical, engineering, and/or scientific principles (e.g., established through operating experience, tests, benchmarking, or acceptance by the scientific community).
NM-B2	If empirical models are used, ENSURE that they are supported by sufficient data, which are relevant to the newly developed method and, to the extent possible, that the experimental data have been shown to be repeatable.
NM-B3	IDENTIFY assumptions used to develop the technical bases of the newly developed method.
NM-B4	JUSTIFY the rationale for the assumptions identified in SR NM-B3 (e.g., backed by appropriate operational experience).

Table 1-7.2-4 Supporting Requirements for HLR-NM-C

The data (note that data can be numeric or non-numeric in nature) shall be relevant to the newly developed method, technically sound, and properly analyzed and applied (HLR-NM-C).

Index No. NM-C	Requirements
NM-C1	IDENTIFY the data needed in the development of the newly developed method (e.g., relevant plant-specific data, industry-wide current operating experience and data, or experimental or test data).
NM-C2	COLLECT relevant data consistent with current technical state of practice.
NM-C3	DEMONSTRATE that the data used, including experimental data or test data, are relevant to and support the technical basis of the newly developed method.
NM-C4	SPECIFY the basis for exclusion of data identified in SR NM-C1.
NM-C5	ANALYZE data (e.g., modifications to the data, use of data in a different context or beyond the original ranges, statistical analysis) using technically sound basis or criteria.
NM-C6	ENSURE that data are applied consistently with the purpose and scope of the newly developed method.

Table 1-7.2-5 Supporting Requirements for HLR-NM-D

Uncertainties in the newly developed method shall be characterized and their potential impact on the newly developed method understood (HLR-NM-D).

Index No. NM-D	Requirements
NM-D1 [Note (1)]	CHARACTERIZE the parameter uncertainties associated with the newly developed method consistent with the intended scope and purpose of the method; this characterization may include, for example, specifying the uncertainty range, qualitatively discussing the uncertainty range, or identifying the parameter estimate as conservative or bounding.
NM-D2	IDENTIFY the sources of model uncertainty associated with assumptions identified in SR NM-B3.
NM-D3	CHARACTERIZE the model uncertainties (identified in SR NM-D2) associated with the newly developed method; this characterization may be in the form of sensitivity studies.

NOTE:
(1) Depending on the purpose and scope of the method, uncertainty distributions may need to be explicitly calculated to allow for application of a method for risk-significant items to meet CC-II of related technical SRs in other Parts of this Standard.

Table 1-7.2-6 Supporting Requirements for HLR-NM-E

The results of the newly developed method shall be reproducible, reasonable, and consistent with the assumptions and data, given the purpose and scope of the newly developed method (HLR-NM-E).

Index No. NM-E	Requirements
NM-E1	REVIEW the results from the newly developed method to determine that they are reproducible, reasonable, and consistent with assumptions and data addressed in the SRs under HLR-NM-B and HLR-NM-C.
NM-E2	COMPARE the results of the newly developed method with existing methods and, when possible, IDENTIFY causes for substantial differences.
NM-E3	ENSURE uncertainties do not preclude meaningful use of the newly developed method results.

Table 1-7.2-7 Supporting Requirements for HLR-NM-F

The documentation of the newly developed method shall provide traceability of the work and facilitate incorporation of the newly developed method in a PRA model (HLR-NM-F).

Index No. NM-F	Requirements
NM-F1	DOCUMENT the newly developed method specifying what is used as input, the technical basis, and the implementation limitations by addressing the following, as well as other details needed to fully document how the set of the newly developed method SRs are satisfied: *(a)* the purpose and scope of the newly developed method *(b)* the intended use of the newly developed method *(c)* the limitations of the newly developed method *(d)* the technical basis for the newly developed method *(e)* the sources of data and the collection process in support of the newly developed method *(f)* the assumptions and uncertainties associated with the newly developed method *(g)* the interpretation of the results of the newly developed method in the framework of the intended use and application
NM-F2	DOCUMENT the intended process by which the newly developed method can be applied to a PRA model consistently with the intended use of the newly developed method and taking into account the purpose, scope, and limitations.

Section 1-8
References

References are cited here and in other Parts of this Standard as guides to the user. The user is cautioned that *(a)* the reference is not to be interpreted that there is a consensus approval on the technical acceptability of the reference and *(b)* there may be more recent versions of the references or alternative documents more pertinent to particular PRA applications.

[1-1] NUREG/CR-1278 and SAND80-0200, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications," A. D. Swain and H. E. Guttmann, Sandia National Laboratories (SNL) (Technique for Human Error Rate Prediction), August 1983; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[1-2] EPRI Report 3002014783, "A Framework for Using Risk Insights in Integrated Risk-Informed Decision-Making," 2019; Publisher: Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[1-3] Regulatory Guide 1.174, Rev. 3, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," January 2018;U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[1-4] NUREG/CR-6372 and UCRL-ID-122160, R. J. Budnitz, D. M. Boore, G. Apostolakis, L. S. Cluff, K. J. Coppersmith, C. A. Cornell, and P. A. Morris, "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts," Lawrence Livermore National Laboratory, April 1997; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[1-5] NUREG/CR-1563, J. P. Kotra, M. P. Lee, N. A. Eisenberg, and A. R. DeWispelare, "Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program," 1996; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

NONMANDATORY APPENDIX 1-A MEANINGS OF ACTION VERBS

This Standard uses action verbs to state requirements. Dictionaries provide multiple meanings for most verbs. Table 1-A-1 states, with examples, the meanings of action verbs as used in this Standard. The relevant dictionary meanings were derived from American dictionaries [e.g., Random House Unabridged (dictionary.com), Merriam-Webster (merriam-webster.com)] with a few modifications to address specific usage in this Standard.

Table 1-A-1 List of Action Verbs

Action Verb	Relevant Dictionary Meaning	Examples of Usage in This Standard
ADDRESS	To direct the efforts or attention to	An example of the appropriate usage of the action verb can be found in SR HR-G3 in Part 2, where CC-I states, when estimating HEPs, ADDRESS specific items.
ADJUST	To bring to a more satisfactory state	An example of the appropriate usage of the action verb can be found in SR WPR-D8 in Part 7, which states ADJUST the credited recovery models based on results of SR WPR-D6.
ANALYZE	To examine critically so as to bring out the essential elements	An example of the appropriate usage of the action verb can be found in SR WHA-C3 in Part 7, where CC-II states ANALYZE thunderstorm and nonthunderstorm data separately.
ASSESS	To determine the importance, size, or value of	An example of the appropriate usage of the action verb can be found in SR QU-C2 in Part 2, which states ASSESS the degree of dependency between HFEs.
ASSOCIATE	To connect or bring into relation	An example of the appropriate usage of this action verb can be found in SR CS-A1 in Part 4, where CC-II states ASSOCIATE cables with equipment failure modes specific to each cable.
ASSUME	To take for granted without proof	An example of the appropriate usage of this action verb can be found in SR SC-A5 in Part 2, where CC-I states ASSUME core damage where stable plant conditions would not be achieved within 24 hrs using modeled plant equipment and human actions.
AUGMENT	To make greater, more numerous, or larger	An example of the appropriate usage of the action verb can be found in SR IE-C13 in Part 2, where CC-I states AUGMENT rare initiating events with applicable generic data sources.
BASE	To make, form, or serve as a base for	An example of the appropriate usage of the action verb can be found in SR DA-C7 in Part 2, where CC-II states BASE the number of unplanned maintenance acts on actual plant experience.
CALCULATE	To determine by mathematical processes, compute	CALCULATE involves a mathematical process, whereas ESTIMATE does not necessarily involve a calculation (e.g., quantification of a probability or frequency) and can be derived qualitatively. An example of the appropriate usage of the action verb can be found in SR LE-D1 in Part 2, which states CALCULATE the containment ultimate capacity for containment challenges.
CHARACTERIZE	To describe the character or quality of	In this Standard, CHARACTERIZE is used with respect to sources of uncertainty. An example of the appropriate usage of the action verb can be found in SR IGN-A9 in Part 4, where CC-I states CHARACTERIZE the uncertainty for those ignition frequencies associated with fire scenarios that are risk-significant contributors.
COLLECT	To bring together into one body or place	An example of the appropriate usage of the action verb can be found in SR SY-A2 in Part 2, which states COLLECT pertinent information to ensure that the systems analysis appropriately represents the as-built, as-operated systems.

Table 1-A-1 List of Action Verbs (Cont'd)

Action Verb	Relevant Dictionary Meaning	Examples of Usage in This Standard
COMPARE	To examine the character or qualities of especially in order to discover similarities or differences	An example of the appropriate usage of the action verb can be found in SR QU-D4 in Part 2, which states COMPARE results to those from similar plants.
COMPILE	To put together (documents, or other materials) in one book or work	An example of the appropriate usage of the action verb can be found in SR XFHA-A1 in Part 8, which states COMPILE a list of flood hazards that are applicable to the site.
COMPLETE	To bring to an end and especially into a perfected state	An example of the appropriate usage of the action verb can be found in SR IFHR-B3 in Part 3, where CC-I and CC-II state COMPLETE the definition of HFEs identified in SR IFHR-B1 and SR IFHR-B2 by including the relevant internal flood-related context.
CONFIRM	To give new assurance of the validity of	An example of the appropriate usage of the action verb can be found in SR WHA-A7 in Part 7, which states CONFIRM that the HW hazard screening correctly represents the as-built, as-operated configuration of the plant.
CONSTRUCT	To make or form by combining or arranging parts or elements	An example of the appropriate usage of the action verb can be found in SR PRM-A2 in Part 4, which states CONSTRUCT the fire PRA plant response model so that it is capable of determining CDFs and LERFs once the fire frequencies are also applied to the quantification.
COUNT	To indicate or name by units or groups so as to find the total number of units involved	An example of the appropriate usage of the action verb can be found in SR DA-C5 in Part 2, which states COUNT repeated plant-specific component failures occurring within a short time interval as a single failure if there is a single, recurring problem that causes the failures.
DO NOT COUNT		An example of the appropriate usage of the action verb can be found in SR DA-C7 in Part 2, which states DO NOT COUNT additional demands from post-maintenance testing.
CREATE	To make or bring into existence something new	An example of the appropriate usage of the action verb can be found in SR IFEV-A2 in Part 3, where CC-I and CC-II state CREATE a new initiating event group if an appropriate initiating event group does not exist.
(TAKE) CREDIT	To account for the impacts or effects of something, which is typically beneficial	In the context of this Standard, CREDIT is a subset of INCLUDE and, as an action verb, is only used in Part 4. Its usage is limited to requirements to including or excluding an item because it provides a potential risk benefit or reduction. Credit is used frequently in the text of Part 3 and Part 4, where it pertains to drains and flood mitigation systems and to fire detection and suppression. An example of appropriate usage of the action verb is in SR CF-A1 in Part 4, where CC-II states CREDIT the mitigating effects of limited hot short duration in the analysis.
DO NOT (TAKE) CREDIT		An example of appropriate usage of the action verb is in SR LE-C9 in Part 2, where CC-I states DO NOT TAKE CREDIT for continued equipment operation or operator actions in adverse environments.
DEFINE	To determine or identify the essential qualities or meaning of	An example of the appropriate usage of the action verb can be found in SR AS-A8 in Part 2, which states DEFINE the end state of the accident sequence as occurring when either a core damage state or a steady state condition has been reached.
DELINEATE	To describe, portray, or set forth with accuracy or in detail	An example of the appropriate usage of the action verb can be found in SR AS-A7 in Part 2, which states DELINEATE the possible accident sequences for each modeled initiating event.
DEMONSTRATE	To prove or make clear by reasoning or evidence	An example of the appropriate usage of the action verb can be found in SR SY-A18 in Part 2, which states DEMONSTRATE that the exclusion of specified conditions do not impact the results.
DERIVE	To receive or obtain especially from a specified source	An example of the appropriate usage of the action verb can be found in SR XHA-A5 in Part 9, which states DERIVE a mean hazard curve accounting for model and parameter uncertainties.
DESCRIBE	To represent or give an account of in words	An example of the appropriate usage of the action verb can be found in SR QU-F2 in Part 2, which states DESCRIBE significant accident sequences or functional failure groups.

Table 1-A-1 List of Action Verbs (Cont'd)

Action Verb	Relevant Dictionary Meaning	Examples of Usage in This Standard
DETERMINE	To find out or come to a decision about by investigation, reasoning, or calculation	An example of the appropriate usage of the action verb can be found in SR XFHA-C7 in Part 8, which states DETERMINE that a following factor is not applicable to the analysis of riverine flooding.
DEVELOP	To bring out the capabilities or possibilities of	An example of the appropriate usage of the action verb can be found in SR AS-B5 in Part 2, which states DEVELOP the accident sequence models to a level of detail sufficient to identify intersystem dependencies and train-level interfaces.
DOCUMENT	To furnish documentary evidence of	An example of the appropriate usage of the action verb can be found in SR AS-C2 in Part 2, which states DOCUMENT the sources of model uncertainty, related assumptions, and reasonable alternatives associated with the accident sequence analysis.
ENSURE	To make sure or certain	An example of the appropriate usage of the action verb can be found in SR QU-D1 in Part 2, which states ENSURE that sufficient accident sequences/cutsets are reviewed to support this conclusion.
ESTABLISH	To bring into being on a firm basis	An example of the appropriate usage of the action verb can be found in SR NM-B1 in Part 1, which states ESTABLISH the technical bases for the newly developed method.
ESTIMATE	To form an approximate judgement or opinion regarding the value, amount, size, etc.; to calculate approximately	ESTIMATE does not necessarily involve a calculation (e.g., quantification of a probability or frequency), and an estimate can be derived qualitatively, whereas CALCULATE involves a mathematical process. An example of the appropriate usage of the action verb can be found in SR HR-G5 in Part 2, where CC-I states ESTIMATE the time required to complete actions when needed for the calculation of an HEP.
EVALUATE	To determine or set the value or amount of; appraise	An example of the appropriate usage of the action verb can be found in SR LE-C12 in Part 2, where CC-I states EVALUTE containment bypass events in a conservative manner.
EXPLAIN	To make plain, clear, or intelligible	An example of the appropriate usage of the action verb can be found in SR IE-C12 in Part 2, which states EXPLAIN differences in the initiating event analysis.
EXTEND	To enlarge the scope of, to make more comprehensive	An example of the appropriate usage of the action verb can be found in SR SHA-A4 in Part 5, which states EXTEND the range of ground motion levels considered to large enough values such that the truncation does not distort final numerical results.
GROUP	*(a)* To combine into one entity *(b)* To assign to a group	GROUP is a verb with two meanings. An example of the first meaning can be found in SR DA-B1 in Part 2, where CC-I states GROUP components according to type for parameter estimation. An example of the second meaning can be found in SR IE-B4 in Part 2, which states GROUP separately from other initiating event categories those categories with different plant-response impacts (i.e., those with different success criteria) or those that could have more severe radionuclide release potential (e.g., LERF).
DO NOT GROUP		An example of the appropriate usage of the action verb can be found in SR IE-B5 in Part 2, which states DO NOT GROUP multi-unit initiating events if they impact mitigation capability.
IDENTIFY	To recognize or establish as being a particular thing	An example of the appropriate usage of the action verb can be found in SR QU-B7 in Part 2, which states IDENTIFY cutsets (or sequences) containing mutually exclusive events in the results.
IMPLEMENT	To put into effect according to or by means of a definite plan or procedure	An example of the appropriate usage of the action verb can be found in SR CC-A1 in Part 1, which states IMPLEMENT a process to track changes, PRA technology, and so on.
INCLUDE	To place in an aggregate, class, category, or the like	An example of the appropriate usage of the action verb can be found in SR IE-A10 in Part 2, which states INCLUDE multi-unit site initiators that may impact the model for multi-unit sites with shared systems.
DO NOT INCLUDE		An example of the appropriate usage of the action verb can be found in SR DA-C1 in Part 2, which states DO NOT INCLUDE generic data for unavailability due to test, maintenance, and repair.

Table 1-A-1 List of Action Verbs (Cont'd)

Action Verb	Relevant Dictionary Meaning	Examples of Usage in This Standard
INTEGRATE	To bring together or incorporate (parts) into a whole	An example of the appropriate usage of the action verb can be found in SR QU-A1 in Part 2, which states INTEGRATE the accident sequences, system models, data, HRA in the quantification process for each initiating event group, accounting for system dependencies, to arrive at accident sequence frequencies.
INTERVIEW	To have a conversation in order to question, consult, or seek information	An example of the appropriate usage of the action verb can be found in SR IE-A8 in Part 2, where CC-II states INTERVIEW plant personnel to determine if potential initiating events have been overlooked.
JUSTIFY	To show a satisfactory reason for some action	An example of the appropriate usage of the action verb can be found in SR LE-C9 in Part 2, where CC-II states JUSTIFY any credit given for equipment survivability or human actions under adverse conditions.
LIMIT	To restrict by establishing criteria	An example of the appropriate usage of the action verb can be found in SR DA-D8 in Part 2, where CC-I states LIMIT the use of old data if modifications to the plant design or operating practice lead to a condition where past data are no longer representative of current performance.
MODEL	To create a representation of	An example of the appropriate usage of the action verb can be found in SR SY-A8 in Part 2, which states MODEL, as separate basic events of the model, those subcomponents that are shared by another component or affect another component or affect another component to the dependent failure mode.
MODIFY	To change somewhat the form or qualities of; alter partially	An example of the appropriate usage of the action verb can be found in SR IE-C9 in Part 2, which states MODIFY, as necessary, the fault-tree computational methods that are used so that the top event quantification produces a failure frequency rather than a top event probability as normally computed.
ORDER	To arrange methodically or suitably	An example of the appropriate usage of the action verb can be found in SR AS-A6 in Part 2, where CC-I and CC-II state ORDER sequentially the events representing the response of the system and operator actions according to the timing of the event as it occurs in the accident progression.
PERFORM	To carry out; execute; do	An example of the appropriate usage of the action verb can be found in SR IE-A5 in Part 2, where CC-I and CC-II state PERFORM a systematic evaluation of each system, including support systems, to assess the possibility of an initiating event occurring due to failure of the system.
PLACE	To put in the proper position or order	An example of the appropriate usage of the action verb can be found in SR AS-B4 in Part 2, which states PLACE Event A to the left of Event B in the ordering of event tops when using event trees with conditional split fraction method.
PROPAGATE	To assess the effect of variables' uncertainties on the uncertainty of a function based on them	PROPAGATE has a specific and special statistical meaning that is not totally captured by the dictionary definition (e.g., "The crack will propagate only to this joint"). When used in this Standard, PROPAGATE is referring to statistical uncertainties. An example of the appropriate usage of the action verb can be found in SR WHA-F2 in Part 7, where CC-II states PROPAGATE the aleatory and epistemic uncertainties that are risk-significant contributors to the HW frequency quantifications.
PROVIDE	To furnish, supply or equip	An example of the appropriate usage of the action verb can be found in SR AS-A6 in Part 2, which states PROVIDE the rationale used for ordering the events representing the response of the systems and operator actions.
QUANTIFY	To determine, indicate, or express the quantity of	An example of the appropriate usage of the action verb can be found in SR SPR-E5 in Part 5, where CC-II states QUANTIFY the mean seismic CDF and seismic LERF.
RETAIN	To keep possession of; to continue to use	An example of the appropriate usage of the action verb can be found in SR QU-C3 in Part 2, which states, when linking event trees, RETAIN the sequence characteristics (e.g., failed equipment, flag settings) that impact the logic or quantification of the subsequent accident development, as well as the sequence frequency.
REVIEW	To go over or examine critically or deliberately	An example of the appropriate usage of the action verb can be found in SR QU-D1 in Part 2, which states REVIEW a sufficiently large sample of the risk-significant accident sequences/cutsets sufficient to determine that the logic of the cutset or sequence is correct.

Table 1-A-1 List of Action Verbs (Cont'd)

Action Verb	Relevant Dictionary Meaning	Examples of Usage in This Standard
SATISFY	To give assurance to; to answer sufficiently	The use of SATISFY is exclusively directed to fulfilling requirements stipulated elsewhere in this Standard, specifically Part 2. An example of the appropriate usage of the action verb can be found in SR SPR-E8 in Part 5, which states SATISFY SR QU-E1 in Part 2 with the additional assumptions in SR SHA-I2, SR SFR-F2, and SR SPR-F3.
SCREEN OUT	To select, reject, consider, or group (objects, ideas, etc.) by a process of winnowing out	In this Standard, the action verb, SCREEN OUT, is not used.
DO NOT SCREEN OUT		An example of the appropriate usage of the action verb can be found in SR HR-B2 in Part 2, which states DO NOT SCREEN OUT activities that could simultaneously have an impact on multiple trains of a redundant system or on diverse systems.
SELECT	To choose in preference to another or others; pick out	An example of the appropriate usage of the action verb can be found in SR QU-A4 in Part 2, which states SELECT a quantification method that is capable of discriminating the contributors to the CDF commensurate with the level of detail in the model.
SPECIFY	To name or state explicitly or in detail	An example of the appropriate usage of the action verb can be found in SR SC-A2 in Part 2, where CC-I states SPECIFY the plant parameters and associated acceptance criteria to be used in determining core damage.
USE	To employ for some purpose, make use of	An example of the appropriate usage of the action verb can be found in SR IE-B2 in Part 2, which states USE a structured, systematic process for grouping initiating events.
DO NOT USE		An example of the appropriate usage of the action verb can be found in SR SY-B11 in Part 2, which states DO NOT USE proceduralized recovery actions as the sole basis for eliminating a support system from the model.

PART 2
REQUIREMENTS FOR INTERNAL-EVENTS AT-POWER PRA

Section 2-1
Overview of Internal-Events At-Power PRA Requirements

2-1.1 PRA SCOPE

This Part states the technical requirements for a Level 1 and large early release frequency (LERF) analysis of the internal-events (excluding internal floods and internal fires) hazard group while at-power.

2-1.2 COORDINATION WITH OTHER PARTS OF THIS STANDARD

This Part is intended to be used together with Part 1 of this Standard. In addition, many of the technical requirements in Part 2 are fundamental requirements for performing a PRA for any hazard group and, therefore, are relevant to Parts 3, 4, 5, 6, 7, 8, and 9 of this Standard. They are incorporated by reference in those requirements that address the development of the plant response to the damage states created by the hazard groups addressed in Parts 3 through 9.

(The text presented in **blue font** in this Standard comprise hyperlinks to enable efficient access to referenced sections and elements, requirements, notes, references, etc.)

Section 2-2
Internal-Events PRA Technical Elements and Requirements

The requirements of this Part are organized into the following eight technical elements:
(a) Initiating Event Analysis (IE)
(b) Accident Sequence Analysis (AS)
(c) Success Criteria (SC)
(d) Systems Analysis (SY)
(e) Human Reliability Analysis (HR)
(f) Data Analysis (DA)
(g) Quantification (QU)
(h) LERF Analysis (LE)

2-2.1 INITIATING EVENT ANALYSIS (IE)

2-2.1.1 Objectives

The objectives of the Initiating Event Analysis are to identify, quantify, and document events that could lead directly (e.g., reactor vessel rupture) or indirectly to core damage in such a way that
(a) there is a reasonably complete identification of initiating events
(b) there is a reasonable set of initiating events that will facilitate the efficient modeling of plant response
(c) frequencies of the initiating events are quantified
(d) the Initiating Event Analysis is documented to provide traceability of the work

Table 2-2.1-1 High Level Requirements for Internal Initiating Event Analysis (IE)

Designator	Requirement
HLR-IE-A	The Initiating Event Analysis shall identify those events that challenge normal plant operation and that require successful mitigation to prevent core damage.
HLR-IE-B	The Initiating Event Analysis shall group the initiating events so that events in the same group have similar mitigation requirements (i.e., the requirements for all events in the group are either equally or less restrictive than the limiting mitigation requirements for the group).
HLR-IE-C	The Initiating Event Analysis shall quantify the annual frequency of each initiating event or initiating-event group.
HLR-IE-D	The documentation of the Initiating Event Analysis shall provide traceability of the work.

Table 2-2.1-2 Supporting Requirements for HLR-IE-A

The Initiating Event Analysis shall identify those events that challenge normal plant operation and that require successful mitigation to prevent core damage (HLR-IE-A).

Index No. IE-A	Capability Category I	Capability Category II
IE-A1	IDENTIFY those initiating events that challenge normal plant operation and that require successful mitigation to prevent core damage by using a structured, systematic process for identifying initiating events that addresses plant-specific features. For example, such a systematic approach may employ one or more of the following: master logic diagrams, heat balance fault trees, or failure modes and effects analysis (FMEA). Existing lists of known initiators are also commonly employed as a starting point.	
IE-A2	INCLUDE in the spectrum of internal-event challenges at least the following general categories: *(a) Transients.* INCLUDE among the transients both equipment and human-induced events that disrupt the plant and leave the primary system pressure boundary intact. *(b) Loss of coolant accidents (LOCAs).* INCLUDE in the LOCA category both equipment and human-induced events that disrupt the plant by causing a breach in the core coolant system with a resulting loss of core coolant inventory. DELINEATE the LOCA initiators using a defined rationale for the delineation. LOCA types include *(1) Small LOCAs:* Examples are reactor coolant pump seal LOCAs, small pipe breaks *(2) Medium LOCAs:* Examples are stuck open safety or relief valves *(3) Large LOCAs:* Examples are inadvertent automatic depressurization system (ADS), component ruptures *(4) Excessive LOCAs* (LOCAs that cannot be mitigated by any combination of engineered systems): Example is reactor pressure vessel (RPV) rupture *(5) LOCAs outside containment:* Example is primary system pipe breaks outside containment [boiling water reactors (BWRs)] *(c) Steam generator tube ruptures (SGTRs).* INCLUDE spontaneous rupture of a steam generator tube [pressurized water reactors (PWRs)]. *(d) High energy line breaks.* Examples are steam line breaks inside and outside containment if not included in the internal flood analysis. *(e) Interfacing systems loss of coolant accidents (ISLOCAs).* INCLUDE postulated events in systems interfacing with the reactor coolant system that could fail or be operated in such a manner as to result in an uncontrolled loss of core coolant outside the containment. *(f)* Special initiators (e.g., support systems failures, instrument line breaks) that may result in either a transient or LOCA-type sequence.	
IE-A3	REVIEW the plant-specific initiating-event experience to ensure that the list of challenges addresses plant experience. See also Supporting Requirement (SR) IE-A7.	
IE-A4	REVIEW generic analyses of similar plants to assess whether the list of challenges included in the model addresses industry experience.	REVIEW generic analyses and operating experience of similar plants to assess whether the list of challenges included in the model addresses industry experience.
IE-A5	PERFORM a systematic evaluation of each system down to the subsystem or train level and including support systems, to assess the possibility of an initiating event occurring due to a failure of the system or train. PERFORM a qualitative review of system impacts to identify potential system initiating events.	PERFORM a systematic evaluation of each system down to the subsystem or train level and including support systems to assess the possibility of an initiating event occurring due to a failure of the system or train. USE a structured approach (e.g., a system-by-system review of initiating-event potential or FMEA or other systematic process) to assess and document the possibility of an initiating event resulting from individual systems or train failures.
IE-A6	When performing the systematic evaluation in SR IE-A5, INCLUDE initiating events resulting from multiple failures if the equipment failures result from a common cause.	When performing the systematic evaluation in SR IE-A5, INCLUDE initiating events resulting from multiple failures, including equipment failures resulting from random or common causes or equipment unavailabilities involving routine system alignments for preventive or corrective maintenance or testing configurations.

Table 2-2.1-2 Supporting Requirements for HLR-IE-A (Cont'd)

The Initiating Event Analysis shall identify those events that challenge normal plant operation and that require successful mitigation to prevent core damage (HLR-IE-A).

Index No. IE-A	Capability Category I	Capability Category II
IE-A7	In the identification of the initiating events, INCLUDE *(a)* events that have occurred at conditions other than at-power operation (i.e., during low-power or shutdown conditions) and for which it is determined that the event could also occur during at-power operation. *(b)* events resulting in an unplanned controlled shutdown that includes a scram prior to reaching low-power conditions, unless it is determined that an event is not applicable to at-power operation.	
IE-A8	INTERVIEW at least one resource knowledgeable in plant design or operation to determine whether potential initiating events have been overlooked.	INTERVIEW plant personnel from various disciplines (e.g., operations, maintenance, engineering, safety analysis) to determine whether potential initiating events have been overlooked.
IE-A9	REVIEW plant-specific licensee event reports (or similar) for initiating-event precursors to identify potential initiating events.	REVIEW plant-specific operating experience for initiating-event precursors to identify additional initiating events. For example, plant-specific experience with intake structure clogging might indicate that loss of intake structures should be identified as a potential initiating event.
IE-A10	For multi-unit sites with shared systems, INCLUDE multi-unit site initiators [e.g., multi-unit loss of off-site power (LOOP) events or total loss of service water] that may impact the model.	
IE-A11	IDENTIFY the initiating-event sources of model uncertainty, the related assumptions, and reasonable alternatives in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 2-2.1-3 Supporting Requirements for HLR-IE-B

The Initiating Event Analysis shall group the initiating events so that events in the same group have similar mitigation requirements (i.e., the requirements for all events in the group are either equally or less restrictive than the limiting mitigation requirements for the group) (HLR-IE-B).

Index No. IE-B	Capability Category I	Capability Category II
IE-B1	GROUP initiating events to facilitate definition of accident sequences in the Accident Sequence Analysis (HLR-AS-A) and to facilitate quantification (HLR-QU-A, HLR-QU-B).	
IE-B2	USE a structured, systematic process for grouping initiating events. For example, such a systematic approach may employ one or more of the following: master logic diagrams, heat balance fault trees, or FMEA.	
IE-B3	GROUP initiating events only when *(a)* events can be considered similar in terms of plant response, success criteria, timing, and the effect on the operability and performance of operators and relevant mitigating systems; or *(b)* events can be bounded by the worst-case impacts within the group.	GROUP initiating events only when *(a)* events can be considered similar in terms of plant response, success criteria, timing, and the effect on the operability and performance of operators and relevant mitigating systems; or *(b)* events can be bounded by the worst-case impacts within the group, and the grouping does not impact risk-significant accident sequences.
IE-B4	GROUP separately from other initiating-event categories those categories with different plant-response impacts (i.e., those with different success criteria) or those that could have more severe radionuclide release potential (e.g., LERF). This includes such initiators as excessive LOCAs, ISLOCAs, SGTRs, and unisolated breaks outside containment.	
IE-B5	For multi-unit sites with shared systems, DO NOT GROUP multi-unit initiating events if they impact mitigation capability.	

Table 2-2.1-4 Supporting Requirements for HLR-IE-C

The Initiating Event Analysis shall quantify the annual frequency of each initiating event or initiating-event group (HLR-IE-C).

Index No. IE-C	Capability Category I	Capability Category II
IE-C1	CALCULATE the initiating-event frequency by addressing applicable generic and plant-specific data that are representative of current design and performance unless there are adequate plant-specific data to characterize the parameter value and its uncertainty (see also SR IE-C13 for requirements for rare events).	
IE-C2	When using generic or plant-specific data, USE data representative of current design and performance to quantify the initiating-event frequencies.	
IE-C3	INCLUDE recovery actions [those implied in SR IE-C6(b)2, and those implied and discussed in SR IE-C11] as appropriate. JUSTIFY each recovery action (e.g., as evidenced through procedures or training).	
IE-C4	When combining evidence from generic and plant-specific data, USE a Bayesian update process or equivalent statistical process. JUSTIFY the selection of any informative prior distribution used on the basis of industry experience.	
IE-C5	CALCULATE initiating-event frequencies on a reactor-year basis [See Table 2-A.2.1-4 in Nonmandatory Appendix (NMA) 2-A.] INCLUDE in the Initiating Event Analysis the plant availability such that the frequencies are weighted by the fraction of time the plant is at-power.	

Table 2-2.1-4 Supporting Requirements for HLR-IE-C (Cont'd)

The Initiating Event Analysis shall quantify the annual frequency of each initiating event or initiating-event group (HLR-IE-C).

<table>
<tr><th>Index No. IE-C</th><th>Capability Category I</th><th>Capability Category II</th></tr>
<tr><td>IE-C6</td><td colspan="2">USE screening criteria at least as stringent as the following characteristics to eliminate initiating events or groups from further evaluation. If other screening criteria are used, ensure that they meet the criteria of Section 1-1.8 and that the bases are justified (as demonstrated per SR QU-D8). The event
(a) does not involve an ISLOCA, is not a containment bypass, does not lead directly to core damage (e.g., RPV rupture), and
(b) either
(1) has the same impact on the plant as another event that has a much higher frequency, per the requirements of SCR-2 in Table 1-1.8-1, or
(2) does not require the plant to go to shutdown conditions until sufficient time has expired during which the initiating-event conditions, with a high degree of certainty (based on supporting calculations), are detected and corrected (either administratively or automatically) such that a complicated shutdown does not occur per the requirements of SCR-3 in Table 1-1.8-1.</td></tr>
<tr><td>IE-C7</td><td>ENSURE data represent plant design and operational performance (as applicable).</td><td>ENSURE data represent current design and operational performance. JUSTIFY data that were excluded as neither current nor applicable (e.g., provide evidence via design or operational change that the data are no longer applicable).</td></tr>
<tr><td>IE-C8</td><td colspan="2">If fault-tree modeling is used for initiating events, USE the applicable systems-analysis requirements for fault-tree modeling found in Systems Analysis (HLR-SY-A).</td></tr>
<tr><td>IE-C9</td><td colspan="2">If fault-tree modeling is used for initiating events, MODIFY, as necessary, the fault-tree computational methods that are used so that the top event quantification produces a failure frequency rather than a top event probability as normally computed. QUANTIFY the initiating-event frequency [as opposed to the probability of an initiating event over a specific time frame, which is the usual fault-tree quantification model described in Systems Analysis (HLR-SY-A)]. USE the applicable requirements in Data Analysis (HLR-DA-C, HLR-DA-D) for the data used in the fault-tree quantification.</td></tr>
<tr><td>IE-C10</td><td colspan="2">If fault-tree modeling is used for initiating events, INCLUDE within the initiating-event fault-tree models the relevant combinations of events involving the annual frequency of one component failure combined with the unavailability (or failure during the repair time of the first component) of other components.</td></tr>
<tr><td>IE-C11</td><td colspan="2">If fault-tree modeling is used for initiating events, USE plant-specific information in the assessment and quantification of recovery actions, as available, in a manner consistent with the applicable requirements in the Human Reliability Analysis (HLR-HR-G, HLR-HR-H).</td></tr>
<tr><td>IE-C12</td><td colspan="2">Where plant-specific information is used, COMPARE results with generic data sources and EXPLAIN differences in the Initiating Event Analysis.</td></tr>
<tr><td>IE-C13</td><td>For rare initiating events, USE industry generic data and INCLUDE plant-specific features to decide which generic data are most applicable. If no industry events have occurred, expert judgment may be used; if used, AUGMENT with applicable generic data sources, and SATISFY the requirements of Section 1-4.2, Use of Expert Judgment.</td><td>For rare initiating events, USE industry generic data and AUGMENT with a plant-specific fault tree or other evaluation that addresses unique plant-specific features. If no industry events have occurred, expert judgment may be used; if used, AUGMENT with applicable generic data sources, and SATISFY the requirements of Section 1-4.2, Use of Expert Judgment. ADDRESS in the quantification the plant-specific features that could influence initiating events and recovery probabilities.</td></tr>
</table>

Table 2-2.1-4 Supporting Requirements for HLR-IE-C (Cont'd)

The Initiating Event Analysis shall quantify the annual frequency of each initiating event or initiating-event group (HLR-IE-C).

Index No. IE-C	Capability Category I	Capability Category II
IE-C14	In the ISLOCA frequency analysis, INCLUDE the following features of plant and procedures that influence the ISLOCA frequency: *(a)* configuration of potential pathways including numbers and types of valves and their relevant failure modes and the existence, size, positioning of relief valves, and behavior of other components (e.g., pump seals, heat exchangers, etc.) *(b)* provision of protective interlocks *(c)* relevant surveillance test procedures *(d)* the capability of secondary system or low-pressure system piping *(e)* isolation capabilities given high flow/differential pressure conditions that might exist following breach of the secondary system	
IE-C15	CALCULATE a point estimate for the initiating-event frequencies. CHARACTERIZE the uncertainty for those initiating-event frequencies associated with risk-significant accident sequences. This characterization could include, for example, specifying the uncertainty range, qualitatively discussing the uncertainty range, or identifying the estimate as conservative or bounding.	CALCULATE a mean value for the frequencies of the risk-significant initiating events. PROVIDE a probabilistic representation of the uncertainty of the parameter estimates of risk-significant initiating events. Acceptable methods include Bayesian updating or expert judgment. If using expert judgment, SATISFY the requirements of Section 1-4.2, Use of Expert Judgment. For the initiating events that are not risk significant, ENSURE the requirement for Capability Category I (CC-I) is met.

Table 2-2.1-5 Supporting Requirements for HLR-IE-D

The documentation of the Initiating Event Analysis shall provide traceability of the work (HLR-IE-D).

Index No. IE-D	Capability Category I	Capability Category II
IE-D1	DOCUMENT the process used in the Initiating Event Analysis, specifying what is used as input, the applied methods, and the results to address the following and other details needed to fully document how the set of SRs is satisfied: *(a)* the functional categories analyzed and the specific initiating events included in each *(b)* the systematic search for plant-unique and plant-specific support system initiators *(c)* the systematic search for reactor coolant system (RCS) pressure boundary failures and interfacing system LOCAs *(d)* the approach for assessing completeness and consistency of initiating events with plant-specific experience, industry experience, other comparable PRAs, and Final Safety Analysis Report (FSAR) initiating events *(e)* the basis for screening out initiating events (refer to criteria in SR IE-C6 and Section 1-1.8) *(f)* the basis for grouping and subsuming initiating events *(g)* the derivation of the initiating-event frequencies and the recoveries used *(h)* the approach to quantification of each initiating-event frequency *(i)* the justification for exclusion of any data	
IE-D2	DOCUMENT the sources of model uncertainty, related assumptions, and reasonable alternatives (as identified in SRs IE-A11, IE-C1, and IE-C15) associated with the Initiating Event Analysis.	

2-2.2 ACCIDENT SEQUENCE ANALYSIS (AS)

2-2.2.1 Objectives

The objectives of the Accident Sequence Analysis element are to ensure that the response of the plant's systems and operators to an initiating event is represented in the assessment of core damage frequency (CDF) in such a way that

(a) the Accident Sequence Analysis describes the plant-specific scenarios that can lead to core damage following each modeled initiating event or initiating event group

(b) plant-specific dependencies are represented in the accident sequence structure

(c) the Accident Sequence Analysis is documented to provide traceability of the work

Table 2-2.2-1 High Level Requirements for Accident Sequence Analysis (AS)

Designator	Requirement
HLR-AS-A	The Accident Sequence Analysis shall ensure that operator actions, mitigation systems, and phenomena that can alter sequences are appropriately included in the accident sequence model event tree structure and sequence definition (consistent with HLR-SC-A) and that end states are clearly defined to be core damage or successful mitigation with capability to support the Level 1 to LERF/Level 2 interface.
HLR-AS-B	Dependencies that can impact the ability of the mitigating systems to operate and function shall be addressed.
HLR-AS-C	The documentation of the Accident Sequence Analysis shall provide traceability of the work.

Table 2-2.2-2 Supporting Requirements for HLR-AS-A

The Accident Sequence Analysis shall ensure that operator actions, mitigation systems, and phenomena that can alter sequences are appropriately included in the accident sequence model event tree structure and sequence definition (consistent with HLR-SC-A) and that end states are clearly defined to be core damage or successful mitigation with capability to support the Level 1 to LERF/Level 2 interface (HLR-AS-A).

Index No. AS-A	Capability Category I	Capability Category II
AS-A1	USE a method for Accident Sequence Analysis that *(a)* explicitly models the combinations of system responses and operator actions that affect the key safety functions for each modeled initiating event *(b)* includes a graphical representation of the accident sequences in an "event tree structure" or equivalent such that the accident sequence progression is displayed *(c)* provides a framework to support sequence quantification	
AS-A2	For each modeled initiating event, IDENTIFY the key safety functions that are necessary to reach a safe, stable state and prevent core damage.	
AS-A3	For each modeled initiating event, by using the success criteria defined for each key safety function (in accordance with SR SC-A3), IDENTIFY the systems that can be used to mitigate the initiator.	
AS-A4	For each modeled initiating event, by using the success criteria defined for each key safety function (in accordance with SR SC-A3), IDENTIFY the necessary operator actions to achieve the defined success criteria.	
AS-A5	DEVELOP the accident sequences in a manner consistent with the plant-specific system design, emergency operating procedures (EOPs), abnormal operating procedures (AOPs), and plant transient response.	
AS-A6	Where practical, sequentially ORDER the events representing the response of the systems and operator actions according to the timing of the event as it occurs in the accident progression. Where not practical, PROVIDE the rationale used for the ordering.	
AS-A7	DELINEATE the possible accident sequences for each modeled initiating event, unless the sequences can be demonstrated to be a noncontribution using qualitative arguments.	
AS-A8	DEFINE the end state of the accident sequence as occurring when either a core damage state or a steady state condition has been reached.	
AS-A9	USE generic thermal-hydraulic analyses (e.g., as performed by a plant vendor for a class of similar plants) to determine the accident progression parameters (e.g., timing, temperature, pressure, steam) that could potentially affect the operability of the mitigating systems.	USE realistic, applicable (i.e., from similar plants) thermal-hydraulic analyses to determine the accident progression parameters (e.g., timing, temperature, pressure, steam) that could potentially affect the operability of the mitigating systems. (See SR SC-B4.)

Table 2-2.2-2 Supporting Requirements for HLR-AS-A (Cont'd)

The Accident Sequence Analysis shall ensure that operator actions, mitigation systems, and phenomena that can alter sequences are appropriately included in the accident sequence model event tree structure and sequence definition (consistent with HLR-SC-A) and that end states are clearly defined to be core damage or successful mitigation with capability to support the Level 1 to LERF/Level 2 interface (HLR-AS-A).

Index No. AS-A	Capability Category I	Capability Category II
AS-A10	In constructing the accident sequence models, INCLUDE, for each modeled initiating event, individual events in the accident sequence sufficient to bound system operation, timing, and operator actions necessary for key safety functions.	In constructing the accident sequence models, INCLUDE, for each modeled initiating event, sufficient detail that differences in requirements of systems and required operator interactions (e.g., systems initiations or valve alignment) are included. Where diverse systems and/or operator actions provide a similar function, if choosing one over another changes the requirements for operator intervention or the need for other systems, MODEL each separately.
AS-A11	Transfers between event trees may be used to reduce the size and complexity of individual event trees. DEFINE any transfers that are used and the method that is used to implement them in the qualitative definition of accident sequences and in their quantification. USE a method for implementing an event-tree transfer that preserves the dependencies that are part of the transferred sequence. These include functional, system, initiating-event, operator, and spatial or environmental dependencies.	
AS-A12	IDENTIFY the accident sequence sources of model uncertainty, related assumptions, and reasonable alternatives in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 2-2.2-3 Supporting Requirements for HLR-AS-B

Dependencies that can impact the ability of the mitigating systems to operate and function shall be addressed (HLR-AS-B).

Index No. AS-B	Capability Category I	Capability Category II
AS-B1	For each modeled initiating event, IDENTIFY mitigating systems that are challenged, degraded, or failed by the occurrence of the initiator and IDENTIFY the specific impacts on the system (e.g., component failures). INCLUDE the impact of initiating events on mitigating systems in the accident progression either in the accident sequence models or in the system models.	
AS-B2	IDENTIFY the dependence of modeled mitigating systems on the success or failure of preceding systems, functions, and human actions. INCLUDE the impact on accident progression, either in the accident sequence models or in the system models. For example, *(a)* turbine-driven system dependency on a solenoid operated relief valve, depressurization, and containment heat removal (suppression pool cooling) *(b)* low-pressure system injection success dependent on need for RPV depressurization	
AS-B3	For each accident sequence, IDENTIFY the phenomenological conditions created by the accident progression. Phenomenological impacts include generation of harsh environments affecting temperature, pressure, debris, water levels, humidity, and so forth that could impact the success of the system or function being analyzed [e.g., loss of pump net positive suction head (NPSH), clogging of flow paths, pipe whip, jet impingement, and other high-energy line-break impacts such as flooding]. INCLUDE the impact of the accident progression phenomena either in the accident sequence models or in the system models.	
AS-B4	When the event trees with the conditional split-fraction method are used, if the probability of Event B is dependent on the occurrence or nonoccurrence of Event A, where practical, PLACE Event A to the left of Event B in the ordering of event tops. Where not practical, DESCRIBE the rationale used for the ordering.	
AS-B5	DEVELOP the accident sequence models to a level of detail sufficient to identify intersystem dependencies and train level interfaces, either in the event trees or through a combination of event-tree and fault-tree models and associated logic.	
AS-B6	If plant configurations or maintenance practices create or alter dependencies between various systems, DEFINE and MODEL these configurations and alignments in a manner that represents these dependencies, either in the accident sequence models or in the system models.	
AS-B7	MODEL time-phased dependencies (i.e., those that change as the accident progresses, due to such factors as depletion of resources, recovery of resources, and changes in loads) in the accident sequences. Examples are as follows: *(a)* For station blackout (SBO)/LOOP sequences, key time-phased events, such as *(1)* alternating current (AC) power recovery *(2)* direct current (DC) battery adequacy (time-dependent discharge) *(3)* environmental conditions (e.g., room cooling) for operating equipment and the control room *(b)* For anticipated transient without scram (ATWS)/failure to scram events (for BWRs), key time-dependent actions, such as *(1)* standby liquid control system (SLCS) initiation *(2)* RPV-level control *(3)* ADS inhibit *(c)* Other events that may be subject to explicit time-dependent characterization, such as *(1)* Control rod drive as an adequate RPV injection source *(2)* long-term makeup to the refueling water storage tank	

Table 2-2.2-4 Supporting Requirements for HLR-AS-C

The documentation of the Accident Sequence Analysis shall provide traceability of the work (HLR-AS-C).

Index No. AS-C	Capability Category I	Capability Category II
AS-C1	DOCUMENT the process used in the Accident Sequence Analysis specifying the processes used to develop accident sequences and to address the dependencies in accident sequences, the inputs, the applied method, the results, and other details needed to fully document how the set of SRs are satisfied: *(a)* the linkage between the modeled initiating event in Initiating Event Analysis (HLR-IE-A) and the accident sequence model (i.e., the key safety functions necessary to reach a safe, stable state and prevent core damage) *(b)* the success criteria established for each modeled initiating event including the bases for the criteria (i.e., the system capacities required to mitigate the accident and the necessary components required to achieve these capacities) *(c)* a description of the accident progression for each sequence or group of similar sequences (i.e., descriptions of the sequence timing, applicable procedural guidance, expected environmental or phenomenological impacts, dependencies between systems and operator actions, end states, and other pertinent information required to fully establish the sequence of events) *(d)* the operator actions represented in the event trees and the sequence-specific timing and dependencies that are traceable to the human reliability analysis (HRA) for these actions *(e)* the interface of the accident sequence models with plant damage states (PDSs) *(f)* when sequences are modeled using a single top-event fault tree, the manner in which the requirements for Accident Sequence Analysis have been satisfied *(g)* mitigating systems that are challenged, degraded, or failed by each specific initiating event and the impact on the system *(h)* the dependence of modeled mitigating systems on the success or failure of preceding systems functions and human actions	
AS-C2	DOCUMENT the sources of model uncertainty, related assumptions, and reasonable alternatives (as identified in SR AS-A12) associated with the Accident Sequence Analysis.	

2-2.3 SUCCESS CRITERIA (SC)

2-2.3.1 Objectives

The objectives of the Success Criteria element are to define the plant-specific measures of success and failure that support the other technical elements of the PRA in such a way that

(a) the success criteria are defined for key safety functions; supporting structures, systems, and components (SSCs); and operator actions necessary to support accident sequence development

(b) the supporting engineering bases are realistic; represent the as-built, as-operated plant; and are consistent with the initiating events and accident sequence models developed in Sections 2-2.1 and 2-2.2

(c) the Success Criteria analysis is documented to provide traceability of the work.

Table 2-2.3-1 High Level Requirements for Success Criteria (SC)

Designator	Requirement
HLR-SC-A	The overall success criteria for the PRA shall be consistent with the features, procedures, and operating philosophy of the plant. This includes defining core damage, establishing accident sequence mission times, and ensuring that mitigating systems shared between units are addressed.
HLR-SC-B	The thermal-hydraulic, structural, and other supporting engineering bases shall be capable of providing success criteria and event timing sufficient for quantification of CDF and determination of the relative impact of success criteria on SSCs and human actions.
HLR-SC-C	The documentation of the Success Criteria analysis shall provide traceability of the work.

Table 2-2.3-2 Supporting Requirements for HLR-SC-A

The overall success criteria for the PRA shall be consistent with the features, procedures, and operating philosophy of the plant. This includes defining core damage, establishing accident sequence mission times, and ensuring that mitigating systems shared between units are addressed (HLR-SC-A).

Index No. SC-A	Capability Category I	Capability Category II
SC-A1	USE the definition of "core damage" provided in Section 1-2 of this Standard. If core damage has been defined differently than in Section 1-2, *(a)* IDENTIFY any substantial differences from the Section 1-2 definition *(b)* SPECIFY the bases for the selected definition	
SC-A2	SPECIFY the plant parameters (e.g., highest node temperature, core collapsed liquid level) and associated acceptance criteria (e.g., temperature limit) to be used in determining core damage.	SPECIFY the plant parameters (e.g., highest node temperature, core collapsed liquid level) and associated acceptance criteria (e.g., temperature limit) to be used in determining core damage. SELECT these parameters such that the determination of core damage is as realistic as practical. SPECIFY computer code-predicted acceptance criteria with sufficient margin on the code-calculated values to allow for limitations of the code, sophistication of the models, and uncertainties in the results, in a manner consistent with the requirements specified under SR HLR-SC-B.
SC-A3	SPECIFY success criteria for each of the key safety functions identified per SR AS-A2 for each modeled initiating event.	
SC-A4	IDENTIFY mitigating systems that are shared between units and the manner in which the sharing is performed should both units experience a common initiating event (e.g., LOOP).	
SC-A5	SPECIFY a sequence mission time for the modeled sequences sufficient to achieve a safe stable state. For sequences in which a safe stable state has been achieved, USE a minimum sequence mission time of 24 hrs. For sequences in which a safe stable state would not be achieved within 24 hrs using the modeled plant equipment and human actions, ASSUME core damage.	SPECIFY a sequence mission time for the modeled sequences sufficient to achieve a safe stable state. For sequences in which a safe stable state has been achieved, USE a minimum sequence mission time of 24 hrs. For sequences in which a safe stable state would not be achieved within 24 hrs using the modeled plant equipment and human actions, PERFORM additional evaluation or modeling by using techniques such as *(a)* assigning a PDS for the sequence *(b)* extending the sequence mission time and adjusting the affected analyses to the point at which a safe stable state can be demonstrated; or *(c)* modeling additional system recovery or operator actions for the sequence, in accordance with requirements stated in Systems Analysis (HLR-SY-A) and Human Reliability Analysis (HLR-HR-H) to demonstrate that a successful outcome is achieved.
SC-A6	ENSURE the component mission time supports the full sequence mission time for which the component is credited or JUSTIFY a shorter component mission time (e.g., 2 hrs is acceptable for SLCS, as the system only has 2 hrs worth of sodium pentaborate to inject). Component mission times for individual SSCs that function during the sequence may be shorter than the sequence mission time, as long as a set of SSCs and operator actions is modeled to support the full sequence mission time.	
SC-A7	ENSURE that the bases for the success criteria are consistent with the features, procedures, and operating philosophy of the plant.	
SC-A8	IDENTIFY the Success Criteria sources of model uncertainty, the related assumptions, and reasonable alternatives in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 2-2.3-3 Supporting Requirements for HLR-SC-B

The thermal-hydraulic, structural, and other supporting engineering bases shall be capable of providing success criteria and event timing sufficient for quantification of CDF and determination of the relative impact of success criteria on SSCs and human actions (HLR-SC-B).

Index No. SC-B	Capability Category I	Capability Category II
SC-B1	DEFINE success criteria by using generic analyses that are applicable to the plant.	DEFINE the realistic success criteria sufficient to mitigate the risk-significant accident sequences based on applicable generic and plant-specific analyses. For non-risk-significant accident sequences, ENSURE the requirement of CC-I is met.
SC-B2	USE expert judgment that meets the requirements of Section 1-4.2, Use of Expert Judgment, in those situations in which there is lack of available information regarding the condition or response of a modeled SSC or a lack of analytical methods on which to base a prediction of SSC condition or response.	
SC-B3	When defining success criteria, USE thermal-hydraulic, structural, or other analyses consistent with the level of detail of the initiating-event grouping (HLR-IE-B) and accident sequence modeling (HLR-AS-A and HLR-AS-B).	
SC-B4	USE analysis models and computer codes that have sufficient capability to model the conditions of interest in the determination of success criteria for core damage and that provide results representative of the plant. A qualitative evaluation of a relevant application of codes, models, or analyses that has been used for a similar class of plant (e.g., Owners Group generic studies) may be used if justified. USE computer codes and models only within known limits of applicability.	
SC-B5	ENSURE the reasonableness and acceptability of the results of the thermal-hydraulic, structural, or other supporting engineering bases used to support the success criteria. Examples of methods to achieve this include *(a)* comparison with results of the same analyses performed for similar plants, addressing differences in unique plant features *(b)* comparison with results of similar analyses performed with other plant-specific codes *(c)* confirmation by other means that have been determined to be appropriate for a particular analysis	
SC-B6	IDENTIFY the sources of model uncertainty, the related assumptions, and reasonable alternatives associated with the thermal hydraulics, structural analyses, and other engineering bases used to develop success criteria in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 2-2.3-4 Supporting Requirements for HLR-SC-C

The documentation of the Success Criteria development shall provide traceability of the work (HLR-SC-C).

Index No. SC-C	Capability Category I / Capability Category II
SC-C1	DOCUMENT the process used in the Success Criteria analysis, specifying what is used as input to address dependencies in accident sequences, including the applied methods, the results, and other details needed to fully document how the set of SRs are satisfied: *(a)* the definition of core damage used in the PRA, including the bases for any selected parameter value used in the definition (e.g., peak cladding temperature or reactor vessel level) *(b)* calculations (generic and plant-specific), empirical data, or other references used to establish success criteria, and identification of cases for which they are used *(c)* identification of computer codes, empirical data, or other methods used to establish plant-specific success criteria *(d)* a description of the limitations (e.g., potential conservatisms or limitations that could challenge the applicability of computer models or data in certain cases) of the calculations or codes *(e)* the uses of expert judgment within the PRA and the rationale for such uses *(f)* a summary of success criteria, and the supporting technical bases for the available mitigating systems and human actions for each accident initiating group modeled in the PRA *(g)* the basis for establishing the time available for human actions *(h)* descriptions of processes used to define success criteria for grouped initiating events or accident sequences *(i)* mitigating systems that are shared between units and the design features of the shared systems, should both units experience a common initiating event
SC-C2	DOCUMENT the sources of model uncertainty, related assumptions, and reasonable alternatives (as identified in SRs SC-A8 and SC-B6) associated with the Success Criteria analysis.

2-2.4 SYSTEMS ANALYSIS (SY)

2-2.4.1 Objectives

The objectives of the Systems Analysis element are to identify and document the causes of failure for each plant system represented in the Initiating Event Analysis and Accident Sequence Analysis in such a way that

(a) there is a reasonably complete set of the independent system-failure and unavailability modes and associated human failure events (HFEs), and system alignments for each system.

(b) there is a reasonably complete identification of the common cause failures (CCFs) and dependency effects on system performance

(c) the Systems Analysis is documented to provide traceability of the work

Table 2-2.4-1 High Level Requirements for Systems Analysis (SY)

Designator	Requirement
HLR-SY-A	System logic models shall be developed that represent the various system alignments, success criteria, and mission times and include the failure modes associated with system maintenance, component actuation and functionality, and associated HFEs.
HLR-SY-B	CCFs and both intersystem and intrasystem dependencies that could influence system performance shall be evaluated and modeled as applicable, including evaluating functional, human, and phenomenological effects.
HLR-SY-C	The documentation of the Systems Analysis shall provide traceability of the work.

Table 2-2.4-2 Supporting Requirements for HLR-SY-A

System logic models shall be developed that represent the various system alignments, success criteria, and mission times and include the failure modes associated with system maintenance, component actuation and functionality, and associated HFEs (HLR-SY-A).

Index No. SY-A	Capability Category I	Capability Category II
SY-A1	IDENTIFY those systems needed to provide or support the safety functions contained in the Accident Sequence Analysis.	
SY-A2	COLLECT pertinent information to ensure that the Systems Analysis represents the as-built, as-operated systems. Examples of such information include system piping and instrumentation drawings, one-line diagrams, instrumentation and control drawings, spatial layout drawings, system operating procedures, AOPs, EOPs, success criteria calculations, the FSAR, Technical Specifications (TS), training information, system descriptions and related design documents, actual system operating experience, and interviews with system engineers and operators.	
SY-A3	REVIEW plant information sources to define or establish *(a)* system components and boundaries *(b)* dependencies on other systems *(c)* instrumentation and control requirements *(d)* testing and maintenance requirements and practices *(e)* operating limitations such as those imposed by TS *(f)* component operability and design limits *(g)* procedures for the operation of the system during normal and accident conditions *(h)* system configuration during normal and accident conditions	
SY-A4	CONFIRM that the Systems Analysis correctly represents the as-built, as-operated plant by performing interviews with knowledgeable plant personnel (engineering, plant operations, etc.).	CONFIRM that the Systems Analysis correctly represents the as-built, as-operated plant by performing plant walkdowns and interviews with knowledgeable plant personnel (engineering, plant operations, etc.).
SY-A5	INCLUDE the effects of both normal and alternate system alignments to the extent needed for CDF determination.	INCLUDE the effects of both normal and alternate system alignments. ENSURE all normal and significant alternate system alignments are modeled. Asymmetrical modeling of trains is permitted if the trains, their support systems, and their underlying data have no significant differences in design and operation.
SY-A6	In defining the system model boundary (see SR SY-A3), INCLUDE within the boundary the components required for system operation and the components providing the interfaces with support systems required for actuation and operation of the system components.	
SY-A7	DEVELOP detailed systems models, unless *(a)* sufficient system-level data are available to quantify the system failure probability, or *(b)* system failure is dominated by operator actions and omitting the model does not mask contributions to the results of support systems or other dependent-failure modes For case *(a)*, USE a single data value only for systems with no equipment or human-action dependencies and if data exist that sufficiently represent the unreliability or unavailability of the system and capture plant-specific factors that could influence unreliability and unavailability. JUSTIFY the use of limited (i.e., reduced or single data value) modeling.	
SY-A8	DEFINE the boundaries of the components required for system operation in a way that is consistent with the component failure data. For example, a control circuit for a pump does not need to be included as a separate basic event (or events) in the system model if the pump failure data used in quantifying the system model include control circuit failures. MODEL, as separate basic events, those subcomponents (e.g., a valve limit switch associated with a permissive signal for another component) that are shared by another component or affect another component, to address the dependent-failure mode.	

Table 2-2.4-2 Supporting Requirements for HLR-SY-A (Cont'd)

System logic models shall be developed that represent the various system alignments, success criteria, and mission times and include the failure modes associated with system maintenance, component actuation and functionality and associated HFEs (HLR-SY-A).

Index No. SY-A	Capability Category I	Capability Category II
SY-A9	If a system model is developed in which a single failure of a supercomponent (or module) is used to represent the collective impact of failures of several components, PERFORM the modularization process in a manner that avoids grouping events with different recovery potential, events that are required by other systems, or events that have probabilities dependent on the scenario. Examples of such events include *(a)* hardware failures that are not recoverable versus actuation signals, which are recoverable *(b)* HFEs that can have different probabilities dependent on the context of different accident sequences *(c)* events that are mutually exclusive of other events not in the module *(d)* events that occur in other fault trees (especially common cause events) *(e)* SSCs that are used by other systems	
SY-A10	INCLUDE the effect of variable success criteria (i.e., success criteria that change as a function of plant status) into the system modeling. Causes of variable system success criteria include the following examples: *(a)* *Different accident scenarios.* Different success criteria are required for some systems to mitigate different accident scenarios (e.g., the number of pumps required to operate in some systems is dependent on the modeled initiating event). *(b)* *Dependence on other components.* Success criteria for some systems are also dependent on the success of another component in the system (e.g., operation of additional pumps in some cooling water systems is required if noncritical loads are not isolated). *(c)* *Time dependence.* Success criteria for some systems are time dependent (e.g., two pumps are required to provide the needed flow early following an accident initiator, but only one is required for mitigation later following the accident). *(d)* *Sharing of a system between units.* Success criteria may be affected when both units are challenged by the same initiating event (e.g., LOOP).	
SY-A11	INCLUDE in the system model those failures of the equipment and components that would affect system operability (as identified in the system success criteria), except when excluded using the criteria in SR SY-A15. This equipment includes both active components (e.g., pumps, valves, and air compressors) and passive components (e.g., piping, screens, heat exchangers, and tanks) required for system operation. When identifying failure modes for the equipment and components in the model, ENSURE those listed in SR SY-A14 are reviewed for applicability.	
SY-A12	DO NOT INCLUDE, in a system model, component failures that would be beneficial to system operation, unless omission would distort the results. Example of a beneficial failure: Failure of an instrument in such a fashion as to generate a required actuation signal.	
SY-A13	INCLUDE those failures that can cause flow-diversion pathways resulting in failure to meet the system success criteria.	

Table 2-2.4-2 Supporting Requirements for HLR-SY-A (Cont'd)

System logic models shall be developed that represent the various system alignments, success criteria, and mission times and include the failure modes associated with system maintenance, component actuation and functionality, and associated HFEs (HLR-SY-A).

Index No. SY-A	Capability Category I	Capability Category II
SY-A14	When identifying the failures in SR SY-A11, INCLUDE failure modes applicable to the component type and consistent with available data and model level of detail, except where excluded using the criteria in SR SY-A15. Examples include the following items: *(a)* failure of an active component to start *(b)* failure of an active component to continue to run *(c)* failure of a closed component to open *(d)* failure of a closed component to remain closed *(e)* failure of an open component to close *(f)* failure of an open component to remain open *(g)* spurious operation of an active component *(h)* plugging of an active or passive component *(i)* leakage of an active or passive component *(j)* rupture of an active or passive component *(k)* internal leakage of a component *(l)* internal rupture of a component *(m)* failure to provide signal or operate (e.g., instrumentation) *(n)* spurious signal/operation *(o)* pre-initiator HFEs (see SR SY-A16) *(p)* other failures of a component to perform its required function	
SY-A15	In meeting SRs SY-A11 and SY-A14, DO NOT INCLUDE contributors to system unavailability and unreliability (i.e., components and specific failure modes) from the model only if one of the following screening criteria is met: *(a)* A component may be excluded from the system model if the total failure probability of the component failure modes resulting in the same effect on system operation is at least two orders of magnitude lower than the highest failure probability of the other components in the same system train that results in the same effect on system operation. *(b)* One or more failure modes for a component may be excluded from the systems model if the contribution to the total failure rate or probability is < 1% of the total failure rate or probability for that component, when their effects on system operation are the same per the requirements of SCR-2 from Table 1-1.8-1, and only one system is impacted.	
SY-A16	In the system model, INCLUDE HFEs that cause the system or component to be unavailable when demanded. These events are referred to as "pre-initiator" human events. (See also Human Reliability Analysis, HLR-HR-C.)	
SY-A17	In the system model, INCLUDE HFEs that are expected during the operation of the system or component unless they are already included explicitly as events in the accident sequence models. These HFEs are referred to as "post-initiator" human events. (See also Human Reliability Analysis, HLR-HR-F, and Accident Sequence Analysis, HLR-AS-A.)	
SY-A18	INCLUDE in either the system model or accident sequence modeling those conditions that cause the system to isolate or trip or that, once exceeded, cause the system to fail or DEMONSTRATE that their exclusion does not impact the results. For example, conditions that isolate or trip a system include *(a)* system-related parameters such as a high temperature within the system *(b)* external parameters used to protect the system from other failures (e.g., the high RPV water-level isolation signal used to prevent water intrusion into the turbines of the reactor core isolation cooling and high pressure coolant injection pumps of a BWR) *(c)* adverse environmental conditions (see SR SY-A22)	

Table 2-2.4-2 Supporting Requirements for HLR-SY-A (Cont'd)

System logic models shall be developed that represent the various system alignments, success criteria, and mission times and include the failure modes associated with system maintenance, component actuation and functionality, and associated HFEs (HLR-SY-A).

Index No. SY-A	Capability Category I	Capability Category II
SY-A19	In the system model, INCLUDE out-of-service unavailability for components, unless excluded per SR SY-A15, in a manner consistent with the actual practices and history of the plant for removing equipment from service. Examples of out-of-service unavailability to be modeled are as follows: *(a)* unavailability caused by testing when a component or system train is reconfigured from its required accident-mitigating position such that the component cannot function as required *(b)* maintenance events at the train level when isolating the entire train for maintenance *(c)* maintenance events at a subtrain level (i.e., between tag-out boundaries, such as a functional equipment group) when directed by procedures *(d)* train outages during a work window for preventive/corrective maintenance *(e)* a functional equipment group removed from service for preventive/corrective maintenance *(f)* a relief valve taken out of service	
SY-A20	INCLUDE events representing the simultaneous unavailability of redundant equipment when the unavailability is a result of planned activity (see SR DA-C14).	
SY-A21	IDENTIFY system conditions that cause a loss of desired system function (excessive heat loads, excessive electrical loads, excessive humidity, etc.).	
SY-A22	INCLUDE a conservative representation of system or component availability when the potential exists for rated or design capabilities to be exceeded.	INCLUDE system or component availability when the potential exists for rated or design capabilities to be exceeded only if supported by one or more of the following: *(a)* test or operational data *(b)* engineering analysis *(c)* expert judgment (SATISFY the requirements of Section 1-4.2, Use of Expert Judgment)
SY-A23	DEFINE system model nomenclature in a consistent manner to allow model manipulation and to represent the same designator when a component failure mode is used in multiple systems or trains.	
SY-A24	DO NOT MODEL the repair of hardware faults, unless the probability of repair is justified through analysis or examination of data. (See SR DA-C15.)	
SY-A25	IDENTIFY the sources of model uncertainty, the related assumptions, and reasonable alternatives associated with the development of the System Analysis in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 2-2.4-3 Supporting Requirements for HLR-SY-B

CCFs and both intersystem and intrasystem dependencies that could influence system performance shall be evaluated and modeled as applicable, including evaluating functional, human, and phenomenological effects (HLR-SY-B).

Index No. SY-B	Capability Category I	Capability Category II
SY-B1	MODEL intrasystem CCFs when supported by generic or plant-specific data or JUSTIFY that they are not a significant contributor to system unreliability.	MODEL intrasystem CCFs when supported by generic or plant-specific data.
SY-B2	DEFINE CCF groups by using a logical, systematic process. JUSTIFY the basis for selecting common-cause component groups by evaluating similarity in *(a)* service conditions *(b)* environment *(c)* design or manufacturer *(d)* maintenance Candidates for CCFs include, for example, *(a)* motor-operated valves *(b)* pumps *(c)* safety-relief valves *(d)* air-operated valves *(e)* solenoid-operated valves *(f)* check valves *(g)* diesel generators *(h)* batteries *(i)* inverters and battery charger *(j)* circuit breakers *(k)* digital instrumentation and controls equipment	
SY-B3	INCLUDE CCFs into the system model in a manner consistent with the common cause model used for Data Analysis. (See SR DA-D6.)	
SY-B4	INCLUDE dependency on support systems or interfacing systems in the modeling process.	
SY-B5	PERFORM engineering analyses to determine the need for support systems that are plant-specific and represent the variability in the conditions present during the postulated accidents for which the system is required to function.	
SY-B6	In support system modeling, USE conservative success criteria and timing.	In support system modeling, USE realistic success criteria and timing for risk-significant contributors.
SY-B7	IDENTIFY spatial and environmental hazards that may impact multiple systems or redundant components in the same system and INCLUDE them in the system fault tree or the accident sequence evaluation.	
SY-B8	When modeling a system, INCLUDE interfaces with the support systems required for successful operation of the system for a required mission time (see also SR SY-A6). Examples of support systems include *(a)* actuation logic *(b)* support systems required for control of components *(c)* component motive power *(d)* cooling of components *(e)* any other identified support function (e.g., heat tracing, digital instrumentation and controls, etc.) necessary to meet the success criteria and associated systems	
SY-B9	JUSTIFY not modeling systems that are required for initiation and actuation of a system (e.g., the initiation and actuation system can be argued to be highly reliable and is only used for that system, so that there are no intersystem dependencies arising from failure of the system).	MODEL those systems that are required for initiation and actuation of a system. For risk-significant systems, include the presence of the conditions needed for automatic actuation (e.g., low vessel water level), and the permissive and lock-out signals that are required to complete actuation logic. For non-risk-significant systems, meet the requirements of CC-I.

Table 2-2.4-3 Supporting Requirements for HLR-SY-B (Cont'd)

CCFs and both intersystem and intrasystem dependencies that could influence system performance shall be evaluated and modeled as applicable, including evaluating functional, human, and phenomenological effects (HLR-SY-B).

Index No. SY-B	Capability Category I	Capability Category II
SY-B10	MODEL the capability of the available inventories of air, power, and cooling to support the component mission time.	
SY-B11	DO NOT USE proceduralized recovery actions as the sole basis for eliminating a support system from the model (e.g., it is not acceptable to not model a system such as heating, ventilation, and air conditioning (HVAC) or component cooling water on the basis that there are procedures for dealing with losses of these systems).	
SY-B12	IDENTIFY SSCs that may be required to operate in conditions beyond their environmental qualifications. INCLUDE dependent failures of multiple SSCs that result from operation in these adverse conditions. Examples of degraded environments include *(a)* LOCA inside containment with failure of containment heat removal *(b)* safety-relief valve operability (small LOCA, drywell spray, severe accident) (for BWRs) *(c)* high-energy line breaks in different locations (e.g., steam line breaks outside containment) *(d)* debris that could plug screens or filters (both internal and external to the plant) *(e)* heating of the water supply (e.g., BWR suppression pool, PWR containment sump) that could affect pump operability *(f)* loss of NPSH for pumps *(g)* steam binding of pumps *(h)* loss of HVAC *(i)* harsh environments induced by containment venting, failure of the containment venting ducts, or failure of the containment boundary that may occur prior to the onset of core damage	
SY-B13	INCLUDE operator interface dependencies across systems or trains, where applicable.	
SY-B14	IDENTIFY the sources of model uncertainty, the related assumptions, and reasonable alternatives associated with the development of the common cause, intersystem dependency, and intrasystem dependency System Analysis modeling in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 2-2.4-4 Supporting Requirements for HLR-SY-C

The documentation of the Systems Analysis shall provide traceability of the work (HLR-SY-C).

Index No. SY-C	Capability Category I	Capability Category II
SY-C1	DOCUMENT the process used in the Systems Analysis, specifying what is used as input, system functions, and boundary; the associated success criteria; the modeled components and failure modes including human actions; and a description of modeled dependencies including support system and CCFs, including the applied methods, the results' and other details needed to fully document how the set of SRs is satisfied: *(a)* system function and operation under normal and emergency operations *(b)* system model boundary *(c)* system schematic illustrating the equipment and components necessary for system operation *(d)* information and calculations to support equipment availability assumptions (e.g., basis for continued operation under excessive heat loads, excessive electrical loads, excessive humidity) *(e)* actual operational history indicating any past problems in the system operation *(f)* system success criteria and relationship to accident sequence models *(g)* human actions necessary for operation of system *(h)* reference to system-related test and maintenance procedures *(i)* system dependencies and shared component interface *(j)* component spatial information, including spatial and environmental hazards that may impact multiple systems or redundant components in the same system *(k)* assumptions or simplifications made in development of the system models *(l)* the components and failure modes included in the model and justification for any exclusion of components and failure modes *(m)* a description of the modularization process (if used) *(n)* records of resolution of logic loops developed during fault-tree linking (if used) *(o)* results of the system model evaluations *(p)* results of sensitivity studies (if used) *(q)* the sources of the above information (e.g., completed checklist from walkdowns, notes from discussions with plant personnel) *(r)* basic events in the system fault trees so that they are traceable to modules and to cutsets *(s)* the nomenclature used in the system models *(t)* the treatment of digital instrumentation and control systems (if used)	
SY-C2	DOCUMENT the sources of model uncertainty, the related assumptions, and reasonable alternatives (as identified in SRs SY-A25, SY-B14) associated with the Systems Analysis.	

2-2.5 HUMAN RELIABILITY ANALYSIS (HR)

2-2.5.1 Objectives

The objective of the Human Reliability Analysis element of the PRA is to ensure that the impacts of plant personnel actions are represented in the assessment of risk. The actions consist of the pre-initiator HFEs and post-initiator HFEs, including the HFEs modeled in the support system initiating-event fault trees.

For pre-initiating events,

(a) identify routine activities that can result in system or SSC unavailability.

(b) ensure that potentially risk-significant plant personnel actions are not screened out.

(c) define a HFE for each retained activity.

(d) use a systematic process to evaluate the pre-initiating-event HFEs.

For *post-initiating events,*

(e) identify post-initiating personnel actions based on plant-specific procedures.

(f) define an HFE for each post-initiating event personnel action.

(g) use a systematic process to evaluate each post-initiating event HFE.

(h) include recovery actions based on accident sequence-specific information, including dependencies between operator actions.

For both pre-initiating and post-initiating events,

(i) document the HRA to provide traceability of the work.

Table 2-2.5-1 High Level Requirements for Human Reliability Analysis (HR)

Designator	Requirement
Pre-Initiator HRA	
HLR-HR-A	A systematic process shall be used to identify those specific routine activities that, if not completed correctly, may impact the availability of equipment necessary to perform system functions modeled in the PRA.
HLR-HR-B	Screening out activities that need not be addressed explicitly in the model shall be based on an assessment of how plant-specific operational practices limit the likelihood of errors in such activities.
HLR-HR-C	For each activity that is not screened out, an HFE shall be defined to characterize the impact of the failure as an unavailability of a component, system, or function modeled in the PRA.
HLR-HR-D	The assessment of the probabilities of the pre-initiator HFEs shall be performed by using a systematic process that addresses the plant-specific and activity-specific influences on human performance.
Post-Initiator HRA	
HLR-HR-E	A systematic review of the relevant procedures shall be used to identify the set of operator responses required for each of the accident sequences.
HLR-HR-F	HFEs shall be defined that represent the impact of not properly performing the required responses, in a manner consistent with the structure and level of detail of the accident sequences.
HLR-HR-G	The assessment of the probabilities of the post-initiator HFEs shall be performed by using a well-defined and self-consistent process that addresses the plant-specific and scenario-specific influences on human performance and addresses potential dependencies between HFEs in the same accident sequence.
HLR-HR-H	Recovery actions (at the cutset or scenario level) shall be modeled only if the actions have been demonstrated to be plausible and feasible for those scenarios to which they are applied. In this context, recovery is associated with operators performing actions to compensate for the failed automatic actions but does not include repair of the equipment.
Pre- and Post-Initiator HRAs	
HLR-HR-I	The documentation of the Human Reliability Analysis shall provide traceability of the work.

Table 2-2.5-2 Supporting Requirements for HLR-HR-A

A systematic process shall be used to identify those specific routine activities that, if not completed correctly, may impact the availability of equipment necessary to perform system functions modeled in the PRA (HLR-HR-A).

Index No. HR-A	Capability Category I	Capability Category II
HR-A1	For equipment modeled in the PRA, IDENTIFY those test, inspection, and maintenance activities that require realignment of equipment outside its normal operational or standby status.	
HR-A2	Through a review of procedures, practices, and plant experience, IDENTIFY those calibration activities that, if performed incorrectly, can have an adverse impact on the initiation and control of risk-significant SSCs that are modeled in the PRA.	
HR-A3	IDENTIFY the work practices identified in SRs HR-A1 and HR-A2 that involve an activity that simultaneously affects equipment in either different trains of a redundant system or diverse systems [e.g., use of common calibration equipment by the same crew on the same shift, a maintenance or test activity that requires realignment of an entire system (e.g., SLCS)].	
HR-A4	IDENTIFY the Pre-Initiator HRA sources of model uncertainty, the related assumptions, and reasonable alternatives in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 2-2.5-3 Supporting Requirements for HLR-HR-B

Screening out activities that need not be addressed explicitly in the model shall be based on an assessment of how plant-specific operational practices limit the likelihood of errors in such activities (HLR-HR-B).

Index No. HR-B	Capability Category I	Capability Category II
HR-B1	If screening is performed, SPECIFY criteria for screening out classes of activities from further analysis, per the requirements of SCR-3 in Table 1-1.8-1. Example: Screen out maintenance and test activities from further analysis if the plant practices are generally structured to include independent verification of restoration of equipment to standby or operational status on completion of the activity.	If screening is performed, SPECIFY criteria for screening out individual activities from further analysis, per the requirements of SCR-3 in Table 1-1.8-1. Example: Screen out maintenance and test activities from further analysis if *(a)* equipment is automatically realigned on system demand; *(b)* following maintenance activities, a postmaintenance, functional test is performed that would reveal misalignment; *(c)* equipment position is indicated in the control room, status is routinely verified, and realignment can be affected from the control room; or *(d)* equipment status is required to be verified frequently (i.e., at least once per shift).
HR-B2	DO NOT SCREEN OUT activities that could simultaneously have an impact on multiple trains of a redundant system or on diverse systems (see SR HR-A3).	

Table 2-2.5-4 Supporting Requirements for HLR-HR-C

For each activity that is not screened out, an HFE shall be defined to characterize the impact of the failure as an unavailability of a component, system, or function modeled in the PRA (HLR-HR-C).

Index No. HR-C	Capability Category I	Capability Category II
HR-C1	DEFINE an HFE that represents the impact of the human failures at the function, system, train, or component level for each activity that was not screened out per SR HR-B1.	
HR-C2	INCLUDE those modes of unavailability that, following completion of each activity that was retained, result from failure to restore *(a)* equipment to the desired standby or operational status *(b)* initiation signal or set point for equipment startup or realignment *(c)* automatic realignment or power	INCLUDE those modes of unavailability that, following completion of each activity that was retained, result from failure to restore *(a)* equipment to the desired standby or operational status *(b)* initiation signal or set point for equipment startup or realignment *(c)* automatic realignment or power INCLUDE failure modes identified during the collection of plant-specific or applicable generic operating experience that leave equipment unavailable for response in accident sequences.
HR-C3	INCLUDE the impact of miscalibration as a mode of failure of initiation and control of risk-significant SSCs that are modeled in the PRA.	

Table 2-2.5-5 Supporting Requirements for HLR-HR-D

The assessment of the probabilities of the pre-initiator HFEs shall be performed by using a systematic process that addresses the plant-specific and activity-specific influences on human performance (HLR-HR-D).

Index No. HR-D	Capability Category I	Capability Category II
HR-D1	SPECIFY the systematic process that will be used to determine the human error probabilities (HEPs).	
HR-D2	USE conservative estimates in the quantification of the pre-initiator HEPs.	For risk-significant pre-initiator HFEs, USE detailed assessments in the quantification of pre-initiator HEP mean values. For non-risk-significant pre-initiator HFEs, ENSURE the requirement for CC-I is met.
HR-D3	USE conservative estimates that take into account the quality of written procedures, administrative controls, or human-machine interfaces.	For each detailed HEP assessment, INCLUDE in the evaluation process the following plant-specific relevant information: *(a)* the quality (e.g., format, logical structure, ease of use, clarity, and comprehensiveness) of written procedures (for performing tasks) and administrative controls that support independent review of written procedures (e.g., configuration control process, technical review process, training processes, and management emphasis on adherence to procedures) *(b)* the quality of the human-machine interface, including both the equipment configuration and the instrumentation and control layout.
HR-D4	When addressing self-recovery or recovery from other crew members in estimating HEPs for specific HFEs, USE pre-initiator recovery factors in a manner consistent with selected methodology. If recovery of pre-initiator errors is credited, *(a)* SPECIFY the maximum credit that can be given for multiple recovery opportunities *(b)* USE the following information to assess the potential for recovery of pre-initiator errors: *(1)* postmaintenance or postcalibration tests required and proceduralized *(2)* independent verification, using a hard-copy or electronic checklist that verifies component status following maintenance/testing *(3)* a separate verification of component status made at a later time, using a hard-copy or electronic checklist, by the original performer *(4)* work-shift or daily verifications of component status, using a hard-copy or electronic checklist	
HR-D5	EVALUATE the potential for dependencies of pre-initiator HFEs (i.e., whether the HFEs have some common elements in their causes, such as work performed by the same crew in the same time frame) and CALCULATE the joint probability of the dependencies identified.	
HR-D6	CHARACTERIZE the uncertainty for the HEPs. This characterization could include, for example, specifying the uncertainty range, qualitatively discussing the uncertainty range, or identifying the estimate as conservative or bounding.	For each risk-significant HFE. PROVIDE a probabilistic representation of the uncertainty of the calculated HEPs. For the HFEs that are not risk significant, ENSURE the requirement for CC-I is met.

Table 2-2.5-6 Supporting Requirements for HLR-HR-E

A systematic review of the relevant procedures shall be used to identify the set of operator responses required for each of the accident sequences (HLR-HR-E).

Index No. HR-E	Capability Category I	Capability Category II
HR-E1	When identifying the operator responses required for each of the accident sequences, REVIEW *(a)* the plant-specific emergency operating procedures and other relevant procedures (e.g., AOPs, annunciator response procedures) in the context of the accident scenarios *(b)* system operation such that the system functions and the human interfaces with the system are understood	
HR-E2	IDENTIFY those actions *(a)* required to initiate (for those systems not automatically initiated), operate, control, isolate, or terminate those systems and components used in preventing or mitigating core damage as defined by the success criteria (e.g., operator initiates residual heat removal) *(b)* performed by the control room personnel either in response to procedural direction or as skill-of-the-craft to diagnose and then recover a failed function, system, or component that is used in the performance of a response action as identified in SR HR-H1	
HR-E3	REVIEW the interpretation of the procedures with plant operations or training personnel to confirm that interpretation is consistent with plant operational and training practices.	USE talk-throughs (i.e., review in detail) with plant operations and training personnel of the procedures and sequence of events to confirm that interpretation of the procedures is consistent with plant observations and training procedures.
HR-E4	REVIEW the interpretation of the human response with plant operations or training personnel to check that interpretation is consistent with expected human response.	USE simulator observations or talk-throughs with operators to confirm the human response actions for scenarios modeled.
HR-E5	IDENTIFY the post-initiator HRA sources of model uncertainty, the related assumptions, and reasonable alternatives in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 2-2.5-7 Supporting Requirements for HLR-HR-F

HFEs shall be defined that represent the impact of not properly performing the required responses, in a manner consistent with the structure and level of detail of the accident sequences (HLR-HR-F).

Index No. HR-F	Capability Category I	Capability Category II
HR-F1	DEFINE HFEs that represent the impact of the human failures at the function, system, train, or component level. Failures to correctly perform several responses may be grouped into one HFE if the impact of the failures is similar or can be conservatively bounded.	
HR-F2	SPECIFY for the defined HFEs *(a)* accident-sequence-specific timing of cues and time window for successful completion *(b)* accident-sequence-specific procedural guidance (e.g., AOPs and EOPs) *(c)* the availability of cues and other indications for detection and evaluation errors *(d)* the complexity of the response (task analysis is not required)	SPECIFY for the defined HFEs *(a)* accident-sequence-specific timing of cues and time window for successful completion *(b)* accident-sequence-specific procedural guidance (e.g., AOPs and EOPs) *(c)* the availability of cues and other indications for detection and evaluation errors *(d)* the specific high-level tasks (e.g., train level) required to achieve the goal of the operator response

Table 2-2.5-8 Supporting Requirements for HLR-HR-G

The assessment of the probabilities of the post-initiator HFEs shall be performed using a well-defined and self-consistent process that addresses the plant-specific and scenario-specific influences on human performance and the potential dependencies between HFEs in the same accident sequence (HLR-HR-G).

Index No. HR-G	Capability Category I	Capability Category II
HR-G1	USE conservative estimates for the HEPs of the HFEs in accident sequences that survive initial quantification.	PERFORM detailed analyses for the estimation of HEPs for risk-significant HFEs. For the HEPs of HFEs that are not risk significant, ENSURE the requirement for CC-I is met.
HR-G2	USE an approach to estimation of HEPs that addresses failure in cognition as well as failure to execute.	
HR-G3	When estimating HEPs, ADDRESS *(a)* the complexity of detection, diagnosis, decision making, and execution of the required response *(b)* the time available and time required to complete the response *(c)* some measure of scenario-induced stress	When estimating HEPs, EVALUATE the impact of the following plant-specific and scenario-specific performance-shaping factors: *(a)* quality [type (classroom or simulator) and frequency] of the operator training or experience *(b)* quality of the written procedures and administrative controls *(c)* availability of instrumentation needed to take corrective actions *(d)* degree of clarity of cues/indications *(e)* human-machine interface *(f)* time available and time required to complete the response *(g)* complexity of detection, diagnosis, decision making, and execution of the required response *(h)* environment (e.g., lighting, heat, radiation) under which the operator is working *(i)* accessibility of the equipment requiring manipulation *(j)* necessity, adequacy, and availability of special tools, parts, clothing, and so on
HR-G4	For the time available to complete actions, USE applicable generic studies (e.g., thermal-hydraulic analysis for similar plants). SPECIFY the point in time at which operators are expected to receive relevant indications.	For the time available to complete actions, USE plant-specific evaluations, realistic generic thermal-hydraulic analyses, or simulations from similar plants (e.g., plant of similar design and operation). SPECIFY the point in time at which operators are expected to receive relevant indications.

Table 2-2.5-8 Supporting Requirements for HLR-HR-G (Cont'd)

The assessment of the probabilities of the post-initiator HFEs shall be performed using a well-defined and self-consistent process that addresses the plant-specific and scenario-specific influences on human performance and the potential dependencies between HFEs in the same accident sequence (HLR-HR-G).

Index No. HR-G	Capability Category I	Capability Category II
HR-G5	When needed for the calculation of an HEP, ESTIMATE the time required to complete actions.	For risk-significant HFEs, ESTIMATE the time required to complete the action based on action-time measurements in either walk-throughs or talk-throughs of procedures or simulator observations. For non-risk-significant HFEs, ENSURE the requirement for CC-I is met.
HR-G6	ENSURE the consistency of the post-initiator HEP quantifications. REVIEW the HFEs and their final HEPs relative to each other to ensure their reasonableness, given the scenario context, plant history, procedures, operational practices, and experience.	
HR-G7	DEFINE a minimum value for the joint probability of multiple human errors occurring in a given cutset or accident sequence, AND JUSTIFY the minimum value to be used for the joint probability of multiple human errors occurring for a given cutset or accident sequence.	
HR-G8	For multiple human actions in the same accident sequence or cutset, ASSESS issues of dependency and CALCULATE a joint HEP. INCLUDE the influence of success or failure in preceding human actions and system performance on the human event being analyzed, including *(a)* time required to complete the actions in relation to the time available to perform the actions *(b)* factors that could lead to dependence (e.g., common instrumentation, common procedures, increased stress, etc.) *(c)* availability of resources (e.g., personnel)	
HR-G9	For multiple human actions in the same accident sequence or cutset, if the joint HEP calculated per SR HR-G8 is below the minimum value from SR HR-G7, USE the minimum value or PROVIDE the technical justification for the use of the lower joint probability based on an applicable evaluation of each cutset or accident sequence with that combination.	
HR-G10	CALCULATE a point-estimate HEP for each HFE. CHARACTERIZE the uncertainty for the calculated HEPs. This characterization could include, for example, specifying the uncertainty range, qualitatively discussing the uncertainty range, or identifying the estimate as conservative or bounding.	CALCULATE a mean HEP for each risk-significant HFE. PROVIDE a probabilistic representation of the uncertainty of the calculated HEPs. For the HFEs that are not risk significant, ENSURE the requirement for CC-I is met.

Table 2-2.5-9 Supporting Requirements for HLR-HR-H

Recovery actions (at the cutset or scenario level) shall be modeled only if the actions have been demonstrated to be plausible and feasible for those scenarios to which they are applied. In this context, recovery is associated with operators performing actions to compensate for the failed automatic actions but does not include repair of the equipment (HLR-HR-H).

Index No. HR-H	Capability Category I	Capability Category II
HR-H1	IDENTIFY operator recovery actions that can restore the functions, systems, or components as needed to provide a more realistic evaluation of risk-significant accident sequences.	
HR-H2	DEFINE operator recovery actions only if, on a plant-specific basis, the following occur: *(a)* A procedure is available and operator training has included the action as part of crew's training, or justification for the omission for one or both is provided. *(b)* "Cues" (e.g., alarms) exist that alert the operator to the recovery action, provided that procedures, training, or skill-of-the-craft also exist. *(c)* Attention is given to the relevant performance-shaping factors provided in SR HR-G3. *(d)* There is sufficient manpower to perform the action.	
HR-H3	ESTIMATE the HEPs for the operator recovery actions in a manner consistent with the applicable CC-I requirements of Section 2-2.5 (SRs HR-G1, HR-G2, HR-G3, HR-G4, HR-G5, HR-G6, and HR-G10).	ESTIMATE the HEPs for the operator recovery actions in a manner consistent with the applicable Capability Category II (CC-II) requirements of Section 2-2.5 (SRs HR-G1, HR-G2, HR-G3, HR-G4, HR-G5, HR-G6, and HR-G10).
HR-H4	INCLUDE any dependency between the HFE for operator recovery and any other HFEs in the sequence, scenario, or cutset to which the recovery is applied (see SRs HR-G7, HR-G8 and HR-G9).	

Table 2-2.5-10 Supporting Requirements for HLR-HR-I

The documentation of the Human Reliability Analysis shall provide traceability of the work (HLR-HR-I).

Index No. HR-I	Capability Category I	Capability Category II
HR-I1	DOCUMENT the process used in the Human Reliability Analysis specifying processes used to identify, characterize, and quantify the pre-initiator, post-initiator, and recovery actions modeled in the PRA, including the inputs, applied methods, the results, and other details needed to fully document how the set of SRs is satisfied: *(a)* HRA methodology and process used to identify pre- and post-initiator HFEs, including identification of the specific tests, inspections, maintenance activities, procedures, and so on, resulting in the HFEs *(b)* screening criteria and results of screening *(c)* factors used in the quantification of the human action, how they were derived, and their bases *(d)* quantification of HEPs, including *(1)* conservative estimates and their bases *(2)* detailed HEP analyses with uncertainties and their bases *(3)* the method and analysis of dependencies for post-initiator actions *(4)* tables of pre- and post-initiator human actions evaluated by model, system, initiating event, and function *(5)* HEPs for recovery actions and their dependency with other HFEs	
HR-I2	DOCUMENT the sources of model uncertainty, related assumptions, and reasonable alternatives (as identified in SRs HR-A4, HR-D6, HR-E5, and HR-G10) associated with the Human Reliability Analysis.	

2-2.6 DATA ANALYSIS (DA)

2-2.6.1 Objectives

The objectives of the Data Analysis element are to provide estimates of the parameters used to determine the probabilities of the basic events representing equipment failures and unavailabilities modeled in the PRA in such a way that

(a) parameter boundaries are defined
(b) components are appropriately grouped
(c) parameter data are consistent with parameter definitions
(d) relevant generic industry and plant-specific evidence are represented in the parameter estimation, including addressing uncertainties
(e) the Data Analysis is documented to provide traceability of the work

Table 2-2.6-1 High Level Requirements for Data Analysis (DA)

Designator	Requirement
HLR-DA-A	Each parameter shall be clearly defined in terms of the logic model, basic event boundary, failure mode, and the model used to evaluate event probability.
HLR-DA-B	Grouping components into a homogeneous population for parameter estimation shall address the design, environmental, and service conditions of the components in the as-built and as-operated plant.
HLR-DA-C	Generic parameter estimates shall be chosen, and collection of plant-specific data shall be consistent with the parameter definitions of HLR-DA-A and the grouping rationale of HLR-DA-B.
HLR-DA-D	The parameter estimates shall be based on relevant generic industry and plant-specific evidence. Where feasible, generic, and plant-specific evidence shall be integrated using acceptable methods to calculate plant-specific parameters. Each parameter estimate shall be accompanied by a characterization of the uncertainty.
HLR-DA-E	The documentation of the Data Analysis shall provide traceability of the work.

Table 2-2.6-2 Supporting Requirements for HLR-DA-A

Each parameter shall be clearly defined in terms of the logic model, basic event boundary, failure mode, and the model used to evaluate event probability (HLR-DA-A).

Index No. DA-A	Capability Category I	Capability Category II
DA-A1	IDENTIFY from the Systems Analysis the basic events for which probabilities are required. Examples of basic events include *(a)* independent failure or CCF of a component or system to start or change state on demand *(b)* independent failure or CCF of a component or system to continue operating or to provide a required function for a defined time period *(c)* equipment unavailable to perform its required function due to being out of service for maintenance *(d)* equipment unavailable to perform its required function due to being in test mode *(e)* failure to recover a function or system (e.g., failure to recover off-site power) *(f)* failure to repair a component, system, or function in a defined time period	
DA-A2	DEFINE SSC boundaries, failure modes, and success criteria in a manner consistent with corresponding basic event definitions in SRs SY-A5, SY-A7, SY-A8, SY-A9, SY-A10, SY-A11, SY-A12, SY-A13, SY-A14, and SY-B3 for failure rates and CCF parameters and DEFINE boundaries of unavailability events in a manner consistent with corresponding definitions in SR SY-A19.	
DA-A3	USE an appropriate probability model for each basic event.	
DA-A4	IDENTIFY the parameter to be estimated and the data required for estimation. Examples are as follows: *(a)* For failures on demand, the parameter is the probability of failure, and the data required are the number of failures given a number of demands. *(b)* For standby failures, operating failures, and initiating events, the parameter is the failure rate, and the data required are the number of failures in the total (standby or operating) time. *(c)* For unavailability due to test or maintenance, the parameter is the unavailability on demand, and the alternatives for the data required are *(1)* the total time of unavailability or a list of the maintenance events with their durations, together with the total time required to be available within the period of plant-specific data collection (see SR DA-C13), or *(2)* the number of maintenance or test activities, their average duration, and the total time required to be available.	
DA-A5	IDENTIFY the Data Analysis sources of model uncertainty, the related assumptions, and reasonable alternatives in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 2-2.6-3 Supporting Requirements for HLR-DA-B

Grouping components into a homogeneous population for parameter estimation shall address the design, environmental, and service conditions of the components in the as-built and as-operated plant (HLR-DA-B).

Index No. DA-B	Capability Category I	Capability Category II
DA-B1	For parameter estimation, GROUP components according to type (e.g., motor-operated pump, air-operated valve).	For parameter estimation, GROUP components according to type (e.g., motor-operated pump, air-operated valve) and according to the characteristics of their usage to the extent supported by data: *(a)* mission type (e.g., standby, operating) *(b)* service condition (e.g., clean vs. untreated water, air) Additional grouping characteristics may also be considered.
DA-B2	DO NOT INCLUDE outliers in the definition of a group (e.g., do not group valves that are never tested and unlikely to be operated with those that are tested or otherwise manipulated frequently).	

Table 2-2.6-4 Supporting Requirements for HLR-DA-C

Generic parameter estimates shall be chosen, and collection of plant-specific data shall be consistent with the parameter definitions of HLR-DA-A and the grouping rationale of HLR-DA-B (HLR-DA-C).

Index No. DA-C	Capability Category I	Capability Category II
DA-C1	USE generic parameter estimates from recognized sources. ENSURE that the parameter definitions and boundary conditions are consistent with those established in response to SRs DA-A1, DA-A2, DA-A3, and DA-A4 (e.g., some sources include the breaker within the pump boundary, whereas others do not). DO NOT INCLUDE generic data for unavailability due to test, maintenance, and repair unless it can be established that the data are consistent with the test and maintenance philosophies for the subject plant.	
DA-C2	COLLECT plant-specific data for the basic event/parameter grouping corresponding to that defined by SRs DA-A1, DA-A3, DA-A4, DA-B1, and DA-B2.	
DA-C3	COLLECT plant-specific data, in a manner consistent with uniformity in design, operational practices, and experience. JUSTIFY the rationale for excluding plant-specific data (e.g., plant design modifications, changes in operating practices).	
DA-C4	When evaluating maintenance or other relevant records to extract plant-specific component failure event data, SPECIFY a basis for the identification of events as failures. DELINEATE between those degraded states for which a failure, as modeled in the PRA, would have occurred during the mission and those for which a failure would not have occurred (e.g., slow pickup to rated speed). INCLUDE the failures that would have resulted in failure to perform the mission as defined in the PRA.	
DA-C5	COUNT repeated plant-specific component failures occurring within a short time interval as a single failure if there is a single, repetitive problem that causes the failures. In addition, COUNT only one demand.	
DA-C6	IDENTIFY procedures that create plant-specific demands on standby components, including *(a)* surveillance tests *(b)* maintenance acts *(c)* TS action statements *(d)* surveillance tests or maintenance on other components *(e)* equipment rotation schedule for operating components	

Table 2-2.6-4 Supporting Requirements for HLR-DA-C (Cont'd)

Generic parameter estimates shall be chosen, and collection of plant-specific data shall be consistent with the parameter definitions of HLR-DA-A and the grouping rationale of HLR-DA-B (HLR-DA-C).

Index No. DA-C	Capability Category I	Capability Category II
DA-C7	EVALUATE the number of demands based on annualized number of surveillance tests and planned maintenance activities per plant procedures.	EVALUATE the number of demands based on actual practice, including plant surveillance and maintenance tests, surveillances required by TS action statements, plant logs, and so on. BASE the number of planned maintenance activities on plant maintenance plans or actual practice. BASE the number of unplanned maintenance activities on actual plant experience. DO NOT COUNT additional demands from postmaintenance testing; that is part of the successful renewal.
DA-C8	When required, EVALUATE the time that components were configured in their standby status.	When required, EVALUATE the time that components were configured in their standby status using plant-specific operational records.
DA-C9	EVALUATE operational time from surveillance test practices for standby components and from actual operational data.	
DA-C10	When using surveillance test data, REVIEW the test procedure to determine whether a test should be credited for each possible failure mode. INCLUDE only completed tests or unplanned operational demands as success for component operations.	When using surveillance test data, REVIEW the test procedure to determine whether a test should be credited for each possible failure mode. INCLUDE only completed tests or unplanned operational demands as success for component operation. If the component failure mode is decomposed into subelements (or causes) that are fully tested, then USE tests that exercise specific subelements in their evaluation. Thus, one subelement sometimes has many more successes than another. (Example: a diesel generator is tested more frequently than the load sequencer. If the sequencer were to be included in the diesel generator boundary, the number of valid tests would be significantly decreased.)
DA-C11	When using data on maintenance and testing durations to estimate unavailabilities at the component, train, or system level, as required by the system model, only INCLUDE those maintenance or test activities that could leave the component, train, or system unable to perform its function when demanded.	
DA-C12	When an unavailability of a frontline system component is caused by an unavailability of a support system, INCLUDE support system unavailability independent of frontline system unavailability to avoid double counting unavailabilities and to include dependency on support system correctly.	

Table 2-2.6-4 Supporting Requirements for HLR-DA-C (Cont'd)

Generic parameter estimates shall be chosen, and collection of plant-specific data shall be consistent with the parameter definitions of HLR-DA-A and the grouping rationale of HLR-DA-B (HLR-DA-C).

Index No. DA-C	Capability Category I	Capability Category II
DA-C13	EVALUATE the duration of the actual time that the equipment was unavailable for each contributing activity. Since maintenance outages are a function of the plant status, INCLUDE only outages occurring during plant at-power. INCLUDE the unavailability of shared systems at a multi-unit site consistently between the units when the TS requirements can be different depending on the status of both units. In the case that reliable estimates of the start and finish times of periods of unavailability are not available, USE conservative estimates.	EVALUATE the duration of the actual time that the equipment was unavailable for each contributing activity. Since maintenance outages are a function of the plant status, INCLUDE only outages occurring during plant at-power. INCLUDE the unavailability of shared systems at a multi-unit site consistently between the units, when the TS requirements can be different depending on the status of both units. In the case that reliable estimates of the start and finish times are not available, INTERVIEW knowledgeable plant personnel (e.g., engineering, plant operations) to generate realistic estimates for ranges in the unavailable-time-per-maintenance act for risk-significant components, trains, or systems.
DA-C14	EVALUATE coincident unavailability due to maintenance for redundant equipment (both intrasystem and intersystem) that is a result of a planned, repetitive activity based on actual plant experience. CALCULATE coincident maintenance unavailabilities that are a result of a planned, repetitive activity that represent actual plant experience. Such coincident maintenance unavailability can arise, for example, for plant systems that have "installed spares" (i.e., plant systems that have more redundancy than is addressed by TS). For example (intrasystem case), the charging system in some plants has a third train that may be out of service for extended periods of time coincident with one of the other trains and yet is in compliance with TS. Examples of intersystem unavailability include plants that routinely take out multiple components on a "train schedule" (e.g., Auxiliary Feedwater Train A and High Pressure Injection Train A at a PWR; Residual Heat Removal Train A and Low Pressure Core Spray Train A at a BWR).	
DA-C15	For each SSC for which repair is to be modeled (see SR SY-A24), IDENTIFY instances of plant-specific or applicable industry experience, and for each repair, COLLECT the associated repair time, with the repair time being the period from identification of the component failure until the component is returned to service, adjusted for accident scenario conditions.	
DA-C16	Data on recovery from loss of off-site power, loss of service water, and so on, are rare on a plant-specific basis. If available, for each recovery, COLLECT the associated recovery time, with the recovery time being the period from identification of the system or function failure until the system or function is returned to service.	

Table 2-2.6-5 Supporting Requirements for HLR-DA-D

The parameter estimates shall be based on relevant generic industry and plant-specific evidence. Where feasible, generic and plant-specific evidence shall be integrated using acceptable methods to calculate plant-specific parameters. Each parameter estimate shall be accompanied by a characterization of the uncertainty (HLR-DA-D).

Index No. DA-D	Capability Category I	Capability Category II
DA-D1	USE plant-specific parameter estimates for events modeling the unique design or operational features if available, or use generic information modified as discussed in SR DA-D2; USE generic information for the remaining events.	CALCULATE realistic parameters for risk-significant basic events based on relevant generic and plant-specific evidence unless it is justified that there are adequate plant-specific data to characterize the parameter value and its uncertainty. When integrating evidence from generic and plant-specific data, USE a statistical process that assigns appropriate weight to the statistical significance of the generic and plant-specific evidence and provides a characterization of uncertainty. Use of either a noninformative prior or one that represents variability in industry data is acceptable. CALCULATE parameters for the remaining events by using generic industry data.
DA-D2	If neither plant-specific data nor generic parameter estimates are available for the parameter associated with a specific basic event, USE data or estimates for the most similar equipment available, adjusting if necessary, to address differences. Alternatively, USE expert judgment and document the rationale behind the choice of parameter values. If using expert judgment, SATISFY the requirements of Section 1-4.2, Use of Expert Judgment.	
DA-D3	CALCULATE a point estimate and CHARACTERIZE the uncertainty for the basic event probabilities. This characterization could include, for example, specifying the uncertainty range, qualitatively discussing the uncertainty range, or identifying the estimate as conservative or bounding.	CALCULATE a mean value for the parameters used to calculate the probabilities of the risk-significant basic events. PROVIDE a probabilistic representation of the uncertainty of the parameter estimates of the risk-significant basic events. Acceptable methods include Bayesian updating or expert judgment. If using expert judgment, SATISFY the requirements of Section 1-4.2, Use of Expert Judgment. For the basic events that are not risk significant, ENSURE the requirement for CC-I is met.
DA-D4	When the Bayesian approach is used to derive a distribution and mean value of a parameter, ENSURE that the posterior distribution is reasonable given the relative weight of evidence provided by the prior and the plant-specific data. Examples of tests to ensure that the updating is accomplished correctly and that the generic parameter estimates are consistent with the plant-specific application include the following: *(a)* confirmation that the Bayesian updating does not produce a posterior distribution with a single-bin histogram *(b)* examination of the cause of any unusual (e.g., multimodal) posterior distribution shapes *(c)* examination of inconsistencies between the prior distribution and the plant-specific evidence to confirm that they are appropriate *(d)* confirmation that the Bayesian updating algorithm provides meaningful results over the range of values being analyzed *(e)* confirmation of the reasonableness of the posterior distribution mean value	

Table 2-2.6-5 Supporting Requirements for HLR-DA-D (Cont'd)

The parameter estimates shall be based on relevant generic industry and plant-specific evidence. Where feasible, generic and plant-specific evidence shall be integrated using acceptable methods to calculate plant-specific parameters. Each parameter estimate shall be accompanied by a characterization of the uncertainty (HLR-DA-D).

Index No. DA-D	Capability Category I	Capability Category II
DA-D5	USE the Beta-factor approach or an equivalent for estimating CCF parameters.	USE one of the following models for estimating CCF parameters for risk-significant basic events for CCF: *(a)* Alpha Factor Model *(b)* Basic Parameter Model *(c)* Multiple Greek Letter Model *(d)* Binomial Failure Rate Model JUSTIFY the use of alternative methods (i.e., provide evidence of peer review or verification of the method that demonstrates its acceptability). For estimating CCF parameters for non-risk-significant basic events for CCF, ENSURE the requirement for CC-I is met.
DA-D6	USE generic CCF parameters. ENSURE the CCF parameters are evaluated in a manner consistent with the component boundaries.	USE CCF parameters consistent with available plant experience. ENSURE the CCF parameters are evaluated in a manner consistent with the component boundaries.
DA-D7	If generic event data are excluded for plant-specific estimation, ENSURE that the generic event data are excluded on both the CCF events and the independent failure events used to generate the CCF parameters.	
DA-D8	If modifications to plant design or operating practice lead to a condition where past data are no longer representative of current performance, LIMIT the use of old data: *(a)* If the modification involves new equipment or a practice where generic parameter estimates are available, USE the generic parameter estimates updated with plant-specific data as data become available for unique design or operational features; or *(b)* If the modification is unique to the extent that generic parameter estimates are not available and only limited experience is available following the change, then ANALYZE the impact of the change and ASSESS the hypothetical effect on the historical data to determine to what extent the data can be used.	If modifications to plant design or operating practice lead to a condition where past data are no longer representative of current performance, LIMIT the use of old data: *(a)* If the modification involves new equipment or a practice where generic parameter estimates are available, USE the generic parameter estimates updated with plant-specific data as data become available for risk-significant basic events; or *(b)* If the modification is unique to the extent that generic parameter estimates are not available and only limited experience is available following the change, then ANALYZE the impact of the change and ASSESS the hypothetical effect on the historical data to determine to what extent the data can be used.

Table 2-2.6-6 Supporting Requirements for HLR-DA-E

The documentation of the Data Analysis shall provide traceability of the work (HLR-DA-E).

Index No. DA-E	Capability Category I	Capability Category II
DA-E1	DOCUMENT the process used in the Data Analysis, specifying data parameter definition, grouping, and collection (including parameter selection and estimation), including what is used as input, the applied methods, the results, and other details needed to fully document how the set of SRs is satisfied: *(a)* system and components requiring data, including the system and component boundaries used to establish component failure probabilities *(b)* the data parameters required, including the data required for estimation and the statistical model used to evaluate each basic event probability *(c)* sources for generic parameter estimates *(d)* the plant-specific sources of data *(e)* the time periods for which plant-specific data were collected *(f)* justification for exclusion of any data *(g)* the basis for the estimates of CCF probabilities, including justification for excluding or mapping of generic and plant-specific data *(h)* the rationale for any distributions used as priors for Bayesian updates, where applicable *(i)* parameter estimate including the characterization of uncertainty	
DA-E2	DOCUMENT the sources of model uncertainty, related assumptions, and reasonable alternatives (as identified in SRs DA-A5, DA-D1, and DA-D3) associated with the Data Analysis.	

2-2.7 QUANTIFICATION (QU)

2-2.7.1 Objectives

The objectives of the Quantification element are to provide an estimate of CDF based on the plant-specific core damage scenarios, in such a way that

(a) the individual parts of the PRA model are integrated to obtain a quantifiable model

(b) the PRA is quantified to obtain reasonable and complete results

(c) human-action dependencies are addressed

(d) risk-significant contributors to CDF are identified and understood in the context of the plant design, operation, and maintenance

(e) analysis limitations and uncertainties are understood

(f) the Quantification is documented to provide traceability of the work

Table 2-2.7-1 High Level Requirements for Quantification (QU)

Designator	Requirement
HLR-QU-A	The individual parts of the Level 1 PRA shall be integrated to allow for quantification of individual accident sequences and the mean CDF and to support the quantification of LERF. The integration shall include the accident sequences, system models, data, and HRA elements and shall account for system dependencies and recovery actions.
HLR-QU-B	Quantification of the PRA shall be performed using appropriate models, codes, a truncation level sufficiently low to show convergence, and shall address method-specific limitations and features. Quantification shall also address the breaking of circular logic, the identification of mutually exclusive event combinations, the use of flag events and modules, and the performance of accident-sequence quantification including the use of system successes.
HLR-QU-C	Model quantification shall be done in a manner such that the identified operator action dependencies are addressed.
HLR-QU-D	The Quantification results shall be reviewed for correctness, completeness, and consistency. The risk-significant contributors to CDF, such as initiating events, accident sequences, and basic events (equipment unavailabilities and HFEs), shall be identified. The results shall be traceable to the inputs and assumptions made in the PRA.
HLR-QU-E	Uncertainties in the PRA results shall be characterized. Sources of model uncertainty and related assumptions shall be identified, and their potential impact on the results understood.
HLR-QU-F	The documentation of the Quantification shall provide traceability of the work.

Table 2-2.7-2 Supporting Requirements for HLR-QU-A

The individual parts of the Level 1 PRA shall be integrated to allow for quantification of individual accident sequences and the mean CDF and to support the quantification of LERF. The integration shall include the accident sequences, system models, data, and HRA elements and shall account for system dependencies and recovery actions (HLR-QU-A).

Index No. QU-A	Capability Category I	Capability Category II
QU-A1	INTEGRATE the accident sequences, system models, data, and HRA in the quantification process for each initiating-event group, accounting for system dependencies, to arrive at accident-sequence frequencies.	
QU-A2	QUANTIFY the frequencies of the individual sequences in a manner consistent with the quantification of total CDF to identify risk-significant accident sequences/cutsets and confirm that the logic is accurately represented. The quantifications may be accomplished by using either fault-tree linking or event trees with conditional split fractions.	
QU-A3	CALCULATE a point-estimate CDF using the point-estimate values for the initiating-event frequencies, HEPs, and basic event probabilities.	QUANTIFY the mean CDF by propagating the uncertainty distributions on the parameters for the risk-significant contributors in such a way that the state-of-knowledge correlation is taken into account, unless it can be demonstrated that the effect of the state of knowledge is not risk significant. For contributors that are not risk significant, an alternative approach is to CALCULATE the mean CDF based on the mean values of the risk-significant input parameters and point estimates for the input parameters that are not risk significant.
QU-A4	SELECT a quantification method that is capable of discriminating the contributors to the CDF commensurate with the level of detail in the model.	
QU-A5	INCLUDE recovery actions in the quantification process in applicable sequences and cutsets (see SRs HR-H1, HR-H2, and HR-H3).	
QU-A6	IDENTIFY the Quantification sources of model uncertainty, the related assumptions, and reasonable alternatives in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 2-2.7-3 Supporting Requirements for HLR-QU-B

Quantification of the PRA shall be performed using appropriate models, codes, a truncation level sufficiently low to show convergence, and shall address method-specific limitations and features. Quantification shall also address the breaking of circular logic, the identification of mutually exclusive event combinations, the use of flag events and modules, and the performance of accident sequence quantification including the use of system successes (HLR-QU-B).

Index No. QU-B	Capability Category I	Capability Category II
QU-B1	PERFORM quantification by using computer codes that have been demonstrated to generate accurate results when compared with those from accepted algorithms. IDENTIFY method-specific limitations and features that could impact the results.	
QU-B2	CONFIRM truncation of accident sequences and associated system models is at a sufficiently low cutoff value such that dependencies associated with risk-significant cutsets or accident sequences are not eliminated. If cutsets are merged to create a solution (e.g., where system-level cutsets are merged to create sequence-level cutsets), then CONFIRM truncation is sufficiently low for the merged cutset solution.	
QU-B3	ESTABLISH truncation limits by an iterative process of demonstrating that the overall model results converge and that no risk-significant accident sequences are inadvertently eliminated. Convergence can be considered sufficient when successive reductions in truncation value of one decade result in decreasing changes in CDF and the final change is less than 5%. Other criteria for convergence can be used when justified.	
QU-B4	Where cutsets are used in quantification, USE the minimal cutset upper bound or an exact solution. JUSTIFY if the rare-event approximation is used.	
QU-B5	VERIFY the methodology used for breaking circular logic associated with fault-tree linking and some other modeling approaches does not introduce unnecessary conservatisms or nonconservatisms.	
QU-B6	INCLUDE system successes in addition to system failures in the evaluation of accident sequences to the extent needed for realistic estimation of CDF. This may be accomplished by using numerical quantification of success probability, complementary logic, or a delete-term approximation, which addresses transfers among event trees where the "successes" may not be transferred between event trees.	
QU-B7	IDENTIFY cutsets (or sequences) containing mutually exclusive events in the results.	
QU-B8	CORRECT cutsets containing mutually exclusive events by either *(a)* developing logic to eliminate mutually exclusive situations, or *(b)* deleting cutsets containing mutually exclusive events	
QU-B9	When using logic flags, SELECT logic flag events as either "True" or "False" (instead of setting the event probabilities to 1.0 or 0.0), as appropriate for each accident sequence, prior to the generation of cutsets.	
QU-B10	If modules, subtrees, or split fractions are used to facilitate the quantification, USE a process that allows *(a)* identification of shared events *(b)* correct formation of modules that are truly independent *(c)* result interpretation based on individual events within modules (e.g., risk significance)	

Table 2-2.7-4 Supporting Requirements for HLR-QU-C

Model quantification shall be done in a manner such that the identified operator-action dependencies are addressed (HLR-QU-C).

Index No. QU-C	Capability Category I	Capability Category II
QU-C1	IDENTIFY cutsets with multiple HFEs that potentially impact risk-significant accident sequences/cutsets. For example, requantify the PRA model with HEP values set to values that are sufficiently high that the cutsets are not truncated.	
QU-C2	ASSESS the degree of dependency between the HFEs in the cutset or sequence in accordance with SRs HR-G7, HR-G8, and HR-G9.	
QU-C3	When linking event trees, RETAIN the sequence characteristics (e.g., failed equipment, flag settings) that impact the logic or quantification of the subsequent accident development, as well as the sequence frequency. For example, sequence characteristics can be transferred to another event tree by using the appropriate cutsets.	

Table 2-2.7-5 Supporting Requirements for HLR-QU-D

The Quantification results shall be reviewed for correctness, completeness, and consistency. The risk-significant contributors to CDF, such as initiating events, accident sequences, and basic events (equipment unavailabilities and HFEs), shall be identified. The results shall be traceable to the inputs and assumptions made in the PRA (HLR-QU-D).

Index No. QU-D	Capability Category I	Capability Category II
QU-D1	REVIEW a sufficiently large sample of the risk-significant accident sequences/cutsets to determine that the logic of the cutset or sequence is correct. ENSURE that sufficient accident sequences/cutsets are reviewed to support this conclusion.	
QU-D2	REVIEW the results of the PRA for modeling consistency (e.g., event sequence model's consistency with systems models and success criteria) and operational consistency (e.g., plant configuration, procedures, and plant-specific and industry experience).	
QU-D3	REVIEW results to determine that the flag event settings, mutually exclusive event rules, and recovery rules yield logical results.	
QU-D4	COMPARE results with those from similar plants if information from similar plants is available.	COMPARE results with those from similar plants if information from similar plants is available and IDENTIFY causes for differences. For example, why is LOCA a large contributor for one plant and not another?
QU-D5	REVIEW a sampling of cutsets or accident sequences that are not risk significant to determine that they are reasonable and have physical meaning.	
QU-D6	IDENTIFY significant contributors to CDF, such as initiating events, accident sequences, equipment failures, CCFs, and operator errors.	IDENTIFY risk-significant contributors to CDF, such as initiating events, accident sequences, equipment failures, CCFs, and operator errors. When evaluating the risk significance of contributors, INCLUDE contributors to the occurrence of both initiating events and event-mitigation failures.
QU-D7	REVIEW the importance of components and basic events to ensure that they are consistent with expected results or to understand and reconcile the reason for the unexpected results.	
QU-D8	PERFORM an assessment to ensure that the cumulative impacts from the initiating events or initiating-event groups screened out under SR IE-C6 do not affect the results or risk-significant contributors for the risk assessment.	

Table 2-2.7-6 Supporting Requirements for HLR-QU-E

Uncertainties in the PRA results shall be characterized. Sources of model uncertainty and related assumptions shall be identified and their potential impact on the results understood (HLR-QU-E).

Index No. QU-E	Capability Category I	Capability Category II
QU-E1	ASSESS the effects of the model uncertainties and related assumptions identified for each technical element by performing a qualitative or quantitative evaluation of the effects of the individual sources of uncertainty or of combinations of interest.	
QU-E2	CHARACTERIZE the uncertainty interval of the CDF results by specifying or discussing the range of the uncertainty, consistent with the characterization of parameter uncertainties (see SRs IE-C15, HR-D6, HR-G10, and DA-D3).	CALCULATE the uncertainty distribution for the CDF results by propagating the uncertainty distributions on the parameters for the risk-significant contributors (initiating events, basic events, and HEPs) to CDF, and those model uncertainties explicitly characterized by a probability distribution in such a way that the state-of-knowledge correlation between component-failure basic event probabilities is accounted for.

Table 2-2.7-7 Supporting Requirements for HLR-QU-F

The documentation of the quantification analysis shall provide traceability of the work and support interpretation of the risk profile for the plant (HLR-QU-F).

Index No. QU-F	Capability Category I	Capability Category II
QU-F1	DOCUMENT the process used in the quantification analysis specifying the integration process, including any recovery analysis, and the results of the quantification including uncertainty analyses, what is used as input, the applied methods, the results, and other details needed to fully document how the set of SRs is satisfied: *(a)* records of the process/results when adding nonrecovery terms as part of the final quantification *(b)* records of the cutset review process *(c)* a general description of the quantification process addressing systems successes, the truncation values used, the application of recovery and post-initiator HFEs, method-specific limitations, and features that could impact the results *(d)* the process and results for establishing the truncation values for final quantification demonstrating that convergence toward a stable result was achieved *(e)* the total plant CDF and contributions from the different initiating events and accident classes *(f)* the accident sequences and their contributing cutsets *(g)* equipment or human actions that are the key factors in causing the accident sequences to not be risk significant *(h)* the uncertainty distribution (as specified for each Capability Category in SR QU-E2) for the total CDF *(i)* importance measure results *(j)* a list of mutually exclusive events eliminated from the resulting cutsets and their bases for elimination *(k)* asymmetries in quantitative modeling to provide application users the necessary understanding of the reasons such asymmetries are present in the model *(l)* the process used to illustrate that the computer code(s) used to perform the quantification will yield correct results *(m)* contributors whose risk significance (or non-risk-significance) is driven by assumptions related to scope or level of detail *(n)* comparison of results to similar plants including causes for risk-significant differences	
QU-F2	DOCUMENT the risk-significant contributors (e.g., initiating events, accident sequences, equipment failures, CCFs, and operator errors, including contributors to both initiating events and event-mitigation failures) to CDF. DESCRIBE risk-significant accident sequences or functional failure groups in accordance with the definitions provided in Section 1-2.2.	
QU-F3	DOCUMENT the sources of model uncertainty, related assumptions, and reasonable alternatives (as identified in SRs QU-A6, QU-E1, and QU-E2) associated with the Quantification.	
QU-F4	DOCUMENT limitations in the quantification process that would impact applications.	

2-2.8 LERF ANALYSIS (LE)

2-2.8.1 Objectives

The objectives of the LERF Analysis element are to identify and quantify the contributors to large early releases, based on the plant-specific core damage scenarios, in such a way that

(a) the physical characteristics of the Level 1 core damage assessment are used to define the PDSs
(b) plant-specific LERF contributors from Table 2-2.8-9 are identified and evaluated
(c) risk-significant accident-progression sequences that have potential for a large early release are identified, evaluated, and understood in the context of the plant design, operation, and maintenance
(d) realistic assessment of containment failures and bypass scenarios is performed
(e) parameter estimates support the LERF assessment
(f) quantitative evaluation of the LERF contributors is performed
(g) analysis limitations and uncertainties are understood
(h) the LERF Analysis is documented to provide traceability of the work

NOTE: In a number of cases, the LERF SRs include references to applicable SRs in other Sections of this Standard (e.g., technical elements Accident Sequence Analysis, Success Criteria, Systems Analysis, Human Reliability Analysis, Data Analysis, and Quantification). The requirements in other Sections of this Standard were primarily written in the context of CDF. Where applicable to LERF, these requirements should be interpreted in the context of LERF. New requirements that are only applicable to LERF are identified in this Section.

Table 2-2.8-1 High Level Requirements for LERF Analysis (LE)

Designator	Requirement
HLR-LE-A	Core damage sequences shall be grouped into PDSs based on their accident progression attributes.
HLR-LE-B	The accident progression analyses shall include an evaluation of contributors (e.g., phenomena, equipment failures, and human actions) to a large early release.
HLR-LE-C	The accident progression analysis shall include a realistic treatment of plant characteristics (containment characteristics, scrubbing effects, equipment survivability, containment bypass potential) and feasible operator actions (repair of equipment, mitigating actions, human actions under adverse environments) to identify those accident progressions that have the potential for a large early release.
HLR-LE-D	The accident progression analysis shall include an evaluation of the containment's ability to prevent a large early release, including the impact of the accident sequence on the structural capability of the containment, the ability of the containment isolation system to contain the release, the potential for a containment bypass to occur (e.g., ISLOCA), and the potential for pressure-induced or thermally-induced SGTRs to occur.
HLR-LE-E	Parameter values selected shall support the evaluation, characterization, and quantification of the accident progression sequences resulting in a large early release.
HLR-LE-F	A quantitative evaluation of the LERF contributors shall be performed, and the risk-significant contributors to LERF, such as PDSs, containment challenges, and failure modes, shall be identified. Sources of model uncertainty and related assumptions shall be identified and their potential impact on the results characterized.
HLR-LE-G	The documentation of the quantification shall provide traceability of the work.

Table 2-2.8-2 Supporting Requirements for HLR-LE-A

Core damage sequences shall be grouped into PDSs based on their accident progression attributes (HLR-LE-A).

Index No. LE-A	Capability Category I	Capability Category II
LE-A1	IDENTIFY those physical characteristics at the time of core damage that can influence LERF. Examples include *(a)* RCS pressure [high RCS pressure can result in high pressure melt ejection (HPME)] *(b)* status of emergency core coolant systems (failure in injection can result in a dry cavity and extensive core concrete interaction) *(c)* status of containment isolation (failure of isolation can result in an unscrubbed release) *(d)* status of containment heat removal *(e)* containment integrity (e.g., vented, bypassed, or failed) *(f)* steam generator pressure and water level (PWRs) *(g)* status of containment inerting (BWRs)	
LE-A2	IDENTIFY the accident sequence characteristics that lead to the physical characteristics identified in SR LE-A1. Examples include *(a)* type of initiator *(1)* transients can result in high RCS pressure *(2)* LOCAs usually result in lower RCS pressure *(3)* ISLOCAs and SGTRs can result in containment bypass *(b)* status of electric power: loss of electric power can result in loss of Emergency Core Cooling System injection *(c)* status of containment safety systems such as sprays, fan coolers, igniters, or venting systems: operability of containment safety systems determines status of containment heat removal	
LE-A3	IDENTIFY how the physical characteristics identified in SR LE-A1 and the accident sequence characteristics identified in SR LE-A2 are addressed in the LERF Analysis. For example, *(a)* which characteristics are addressed in the Level 1 event trees *(b)* which characteristics, if any, are addressed in bridge trees *(c)* which characteristics, if any, are addressed in the containment event trees JUSTIFY any characteristics identified in SR LE-A1 or LE-A2 that are excluded from the LERF Analysis (e.g. no risk-significant impact on release timing or magnitude)	
LE-A4	PROVIDE a method to explicitly account for dependencies between the Level 1 PRA and LERF/Level 2 PRA models as identified in SRs LE-A1 and LE-A2. Example methods include *(a)* treatment in LERF/Level 2 PRA *(b)* expanding Level 1 PRA *(c)* construction of a bridge tree *(d)* transfer of the information via PDS *(e)* a combination of the above methods	
LE-A5	DEFINE PDSs in a manner consistent with SRs LE-A1, LE-A2, LE-A3, and LE-A4.	

Table 2-2.8-3 Supporting Requirements for HLR-LE-B

The accident progression analysis shall include an evaluation of contributors (e.g., phenomena, equipment failures, and human actions) to a large early release (HLR-LE-B).

Index No. LE-B	Capability Category I	Capability Category II
LE-B1	IDENTIFY LERF contributors from the set identified in Table 2-2.8-9. INCLUDE plant-specific LERF contributors as determined by expert judgment (SATISFY the requirements of Section 1-4.2, Use of Expert Judgment) and/or engineering analyses.	IDENTIFY LERF contributors from the set identified in Table 2-2.8-9 and other lessons. INCLUDE plant-specific LERF contributors as determined by expert judgment (SATISFY the requirements of Section 1-4.2, Use of Expert Judgment) and/or engineering analyses.
LE-B2	CALCULATE the containment challenges (e.g., temperature, pressure loads, debris impingement) resulting from contributors identified in SR LE-B1 using applicable generic analyses. Where applicable generic analyses are not available, conservative plant-specific analyses may be used.	CALCULATE the containment challenges (e.g., temperature, pressure loads, debris impingement) resulting from contributors identified in SR LE-B1 using applicable generic or plant-specific analyses for risk-significant containment challenges. USE conservative analysis or a combination of conservative and realistic analysis for containment challenges that are not risk significant. If generic calculations are used in support of the assessment, JUSTIFY applicability to the plant being evaluated (e.g., consistent with, or envelope, the plant-specific design features and values).
LE-B3	USE supporting engineering analyses in accordance with the applicable CC-I requirements of HLR-SC-A and HLR-SC-B.	USE supporting engineering analyses in accordance with the applicable CC-II requirements of HLR-SC-A and HLR-SC-B.

Table 2-2.8-4 Supporting Requirements for HLR-LE-C

The accident progression analysis shall include a realistic treatment of plant characteristics (containment characteristics, scrubbing effects, equipment survivability, containment bypass potential) and feasible operator actions (repair of equipment, mitigating actions, human actions under adverse environments) to identify those accident progressions that have the potential for a large early release (HLR-LE-C).

Index No. LE-C	Capability Category I	Capability Category II
LE-C1	DEVELOP accident sequences to a level of detail to account for the potential contributors identified in SR LE-B1 and analyzed in SR LE-B2.	DEVELOP accident sequences to a level of detail to account for the potential contributors identified in SR LE-B1 and analyzed in SR LE-B2. COMPARE the containment challenges analyzed in HLR-LE-B with the containment structural capability analyzed in HLR-LE-D and identify accident progressions that have the potential for a large early release. JUSTIFY any generic or plant-specific calculations or references used to categorize releases as non-LERF contributors based on release magnitude or release timing.
LE-C2	USE conservative estimates for the HEPs of the feasible operator actions following the onset of core damage.	PERFORM detailed analysis for the estimation of HEPs of feasible, risk-significant operator actions following the onset of core damage consistent with applicable procedures or guidance (e.g., EOPs or Severe Accident Management Guidelines, proceduralized actions, or Technical Support Center guidance).
LE-C3	If crediting repair, ENSURE the credit given is conservative.	If crediting repair, REVIEW risk-significant accident sequences resulting in a large early release to determine whether repair of equipment can be credited. JUSTIFY credit given for repair (i.e., ensure that plant conditions do not preclude repair and that actuarial data exist from which to estimate the repair failure probability, as required by SRs SY-A24 and DA-C15). AC power recovery based on generic data applicable to the plant is acceptable.
LE-C4	INCLUDE accident progression sequence model logic necessary to provide sequences resulting in a large early release.	INCLUDE accident progression sequence model logic necessary to provide an estimation of the risk-significant sequences resulting in a large early release. INCLUDE mitigating actions by operating personnel, effect of fission product scrubbing on radionuclide release, and expected beneficial failures in risk-significant accident progression sequences. PROVIDE technical justification (by plant-specific or applicable generic calculations demonstrating the feasibility of the actions, scrubbing mechanisms, or beneficial failures) supporting the inclusion of any of these features.
LE-C5	USE conservative, generic analyses of system success criteria that are applicable to the plant.	USE realistic generic or plant-specific analyses for system success criteria for the risk-significant accident progression sequences. USE conservative or a combination of conservative and realistic system success criteria for accident progression sequences that are not risk significant.

Table 2-2.8-4 Supporting Requirements for HLR-LE-C (Cont'd)

The accident progression analysis shall include a realistic treatment of plant characteristics (containment characteristics, scrubbing effects, equipment survivability, containment bypass potential) and feasible operator actions (repair of equipment, mitigating actions, human actions under adverse environments) to identify those accident progressions that have the potential for a large early release (HLR-LE-C).

Index No. LE-C	Capability Category I	Capability Category II
LE-C6	DEVELOP system models and data to support the accident progression analysis in a manner consistent with the applicable CC-I requirements for HLR-SY-A, HLR-SY-B, HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D for the level of detail of the analysis.	MODEL systems and use data to support the accident progression analysis in a manner consistent with the applicable CC-II requirements for HLR-SY-A, HLR-SY-B, HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D, for the level of detail of the analysis.
LE-C7	In crediting success criteria and HFEs that support the accident progression analysis, USE the applicable CC-I requirements of HLR-AS-A, HLR-HR-C, HLR-HR-F, and HLR-HR-H for the level of detail of the analysis.	In crediting success criteria and HFEs that support the accident progression analysis, USE the applicable CC-II requirements of HLR-AS-A, HLR-HR-C, HLR-HR-F, and HLR-HR-H for the level of detail of the analysis.
LE-C8	INCLUDE accident sequence dependencies in the accident progression sequences in a manner consistent with the applicable CC-I requirements of HLR-AS-A and HLR-AS-B for the level of detail of the analysis.	INCLUDE accident sequence dependencies in the accident progression sequences in a manner consistent with the applicable CC-II requirements of HLR-AS-A and HLR-AS-B for the level of detail of the analysis.
LE-C9	DO NOT TAKE CREDIT for continued equipment operation or operator actions in adverse environments (i.e., beyond equipment qualification limits).	JUSTIFY credit given for equipment survivability or human actions under adverse environments (e.g., based on an evaluation of environmental conditions allowing human actions and system or documented component environmental qualification).
LE-C10	USE conservative or a combination of conservative and realistic treatments of adverse environmental impacts if crediting equipment survivability inside containment. For example, it can be assumed that equipment inside containment does not survive when subjected to environments beyond the equipment's qualification limits. Examples include the following: *(a)* SRV operation at high containment temperature *(b)* vent valve operation at high containment pressure *(c)* motor-operated valve operation if located inside containment	
LE-C11	USE conservative or a combination of conservative and realistic treatments of adverse environmental impacts if crediting human actions or equipment survivability outside containment. For example, it can be assumed that equipment outside containment does not survive after containment failure if the adverse impacts of containment failure could affect operability, survivability, or alignment of the equipment.	
LE-C12	EVALUATE containment bypass events in a conservative manner. If crediting scrubbing, then ENSURE the credit given is conservative.	PERFORM a containment bypass analysis in a realistic manner. JUSTIFY any credit taken for scrubbing (i.e., provide an engineering basis for the decontamination factor used).

Table 2-2.8-5 Supporting Requirements for HLR-LE-D

The accident progression analysis shall include an evaluation of the containment's ability to prevent a large early release, including the impact of the accident sequence on the structural capability of the containment, the ability of the containment isolation system to contain the release, the potential for a containment bypass to occur (e.g., ISLOCA), and the potential for pressure-induced or thermally-induced SGTRs to occur (HLR-LE-D).

Index No. LE-D	Capability Category I	Capability Category II
LE-D1	CALCULATE the containment ultimate capacity for the containment challenges that result in a large early release. USE a conservative containment capacity analysis for containment challenges. If generic assessments formulated for similar plants are used, JUSTIFY applicability to the plant being evaluated (e.g., similar containment designs or estimating containment capacity based on design pressure and a conservative multiplier relating containment design pressure and median ultimate failure pressure).	CALCULATE the containment ultimate capacity for the containment challenges that result in a large early release. PERFORM a realistic containment capacity analysis for the risk-significant containment challenges. If available, existing generic containment design specific analyses applicable to the plant may be used. For containment challenges that are not risk significant, ENSURE the requirement for CC-I is met. Static containment capability evaluations are acceptable unless hydrogen concentrations are expected to result in potential detonations: INCLUDE such considerations for small-volume containments (e.g., ice-condenser type).
LE-D2	EVALUATE the impact of containment seals, penetrations, hatches, drywell heads (BWRs), and vent piping bellows and INCLUDE as potential containment failures, as required.	EVALUATE the impact of containment seals, penetrations, hatches, drywell heads (BWRs), and vent pipe bellows and INCLUDE as potential containment failures, as required. If generic analyses are used in support of the assessment, JUSTIFY applicability to the plant being evaluated (e.g., similar failure locations in similar containment designs).
LE-D3	When containment failure location affects the classification of the accident progression as a large early release, SPECIFY failure location based on a containment assessment that addresses plant-specific features. JUSTIFY applicability of generic and other analyses (e.g., similar failure locations in similar containment designs).	When containment failure location affects the event classification of the accident progression as a large early release, SPECIFY failure location based on a realistic containment assessment that addresses plant-specific features. If generic analyses are used in support of the assessment, JUSTIFY applicability to the plant being evaluated (e.g., similar failure locations in similar containment designs).
LE-D4	USE a conservative evaluation of interfacing system failure probability for accident progression sequences resulting in a large early release. If generic analyses generated for similar plants are used, JUSTIFY applicability to the plant being evaluated (e.g., similar interfacing systems and similar containment designs).	PERFORM a realistic interfacing system failure probability analysis for the risk-significant accident progression sequences resulting in a large early release. USE a conservative or a combination of conservative and realistic evaluation of interfacing system failure probability for accident progression sequences that are not risk significant that result in a large early release. INCLUDE behavior of piping, relief valves, pump seals, and heat exchangers at applicable temperature and pressure conditions.
LE-D5	USE a conservative evaluation of secondary side isolation capability for accident sequences caused by SGTR resulting in a large early release. If generic analyses generated for similar plants are used, JUSTIFY applicability to the plant being evaluated (e.g., similar isolation capability and similar containment designs).	PERFORM a realistic secondary side isolation capability analysis for the risk-significant accident sequences caused by SGTR resulting in a large early release. USE a conservative or a combination of conservative and realistic evaluation of secondary side isolation capability for accident sequences that are not risk significant that result in a large early release. JUSTIFY applicability to the plant being evaluated (e.g., similar isolation capability and similar containment designs).

Table 2-2.8-5 Supporting Requirements for HLR-LE-D (Cont'd)

The accident progression analysis shall include an evaluation of the containment's ability to prevent a large early release, including the impact of the accident sequence on the structural capability of the containment, the ability of the containment isolation system to contain the release, the potential for a containment bypass to occur (e.g., ISLOCA), and the potential for pressure-induced or thermally-induced SGTRs to occur (HLR-LE-D).

Index No. LE-D	Capability Category I	Capability Category II
LE-D6	PERFORM a conservative analysis of thermally-induced SGTR that includes plant-specific procedures.	PERFORM an analysis of thermally-induced SGTR that includes plant-specific procedures and design features and conditions that could impact tube failure. SELECT failure probabilities based on *(a)* RCS and steam generator postaccident conditions sufficient to describe the risk-significant outcomes *(b)* secondary side conditions including plant-specific analysis of main steam safety valve and atmospheric dump valve failures JUSTIFY assumptions and selection of key inputs.
LE-D7	PERFORM containment isolation analysis in a conservative manner, including analysis of the failure of containment isolation systems to perform as designed and the status of safety systems that do not have automatic isolation provisions.	PERFORM containment isolation analysis in a realistic manner for the risk-significant accident progression sequences resulting in a large early release, including analysis of the failure of containment isolation systems to perform as designed and the status of safety systems that do not have automatic isolation provisions. For the accident progression sequences that are not risk significant, ENSURE the requirement of CC-I is met.

Table 2-2.8-6 Supporting Requirements for HLR-LE-E

Parameter values selected shall support the evaluation, characterization, and quantification of the accident progression sequences resulting in a large early release (HLR-LE-E).

Index No. LE-E	Capability Category I	Capability Category II
LE-E1	SELECT parameter values for equipment and operator response in the accident progression analysis in a manner consistent with the applicable CC-I requirements of Section 2-2.5 (HLR-HR-D, HLR-HR-G, HLR-HR-H) and Section 2.2-6 (HLR-DA-C, HLR-DA-D), including analysis of the severe-accident plant conditions, as appropriate for the level of detail of the analysis.	SELECT parameter values for equipment and operator response in the accident progression analysis in a manner consistent with the applicable CC-II requirements of Section 2-2.5 (HLR-HR-D, HLR-HR-G, HLR-HR-H) and Section 2.2-6 (HLR-DA-C, HLR-DA-D), including analysis of the severe-accident plant conditions, as appropriate for the level of detail of the analysis.
LE-E2	USE conservative parameter estimates to characterize accident progression phenomena.	USE realistic parameter estimates to characterize accident progression phenomena for risk-significant accident progression sequences resulting in a large early release. For accident progression sequences that are not risk significant that result in a large early release, ENSURE the requirement of CC-I is met.
LE-E3	INCLUDE as LERF contributors potential large early release sequences in a conservative manner, that is, designate early containment failures, bypass sequences, and isolation failures as LERF contributors.	INCLUDE as LERF contributors potential large early release sequences identified from the results of the accident progression analysis of HLR-LE-C except those large early release sequences justified as non-LERF contributors in SR LE-C1.
LE-E4	QUANTIFY LERF in a manner consistent with the applicable requirements of HLR-QU-A, HLR-QU-B, and HLR-QU-C. For SR QU-A3, meet the requirements of the desired Capability Category.	

Table 2-2.8-7 Supporting Requirements for HLR-LE-F

A quantitative evaluation of the LERF contributors shall be performed, and the risk-significant contributors to LERF, such as PDSs, containment challenges, and failure modes, shall be identified. Sources of model uncertainty and related assumptions shall be identified and their potential impact on the results characterized (HLR-LE-F).

Index No. LE-F	Capability Category I	Capability Category II
LE-F1	IDENTIFY the significant contributors to large early releases (e.g., PDSs, containment failure modes).	IDENTIFY risk-significant contributors to LERF. INCLUDE contributors associated with each of the PDSs from Table 2-2.8-9.
LE-F2	REVIEW contributors for reasonableness (e.g., to ensure that excessive conservatisms have not skewed the results, that level of plant specificity is appropriate for risk-significant contributors) in a manner consistent with the applicable CC-I requirements of Table 2-2.7-5 (HLR-QU-D).	REVIEW contributors for reasonableness (e.g., to ensure that excessive conservatisms have not skewed the results, that level of plant specificity is appropriate for risk-significant contributors) in a manner consistent with the applicable CC-II requirements of Table 2-2.7-5 (HLR-QU-D).
LE-F3	IDENTIFY the LERF sources of model uncertainty, the related assumptions, and reasonable alternatives, in a manner consistent with the applicable CC-I requirements of Table 2-2.7-6 (HLR-QU-E).	IDENTIFY the LERF sources of model uncertainty, the related assumptions, and reasonable alternatives, in a manner consistent with the applicable CC-II requirements of Table 2-2.7-6 (HLR-QU-E).

Table 2-2.8-8 Supporting Requirements for HLR-LE-G

The documentation of the LERF Analysis shall provide traceability of the work and support interpretation of the risk profile for the plant (HLR-LE-G).

Index No. LE-G	Capability Category I	Capability Category II
LE-G1	DOCUMENT the process used in the LERF Analysis specifying what is used to identify PDSs and accident progression contributors, define accident progression sequences, evaluate accident progression analyses of containment capability, and quantify and review the LERF results, inputs, the applied method, the results, and other details needed to fully document how the set of SRs is satisfied: *(a)* the accident sequence characteristics and the PDSs, including their physical attributes, as addressed in the analysis *(b)* the method used to bin the accident sequences into PDSs, including the identification of LERF contributors *(c)* the containment failure modes, phenomena, equipment failures, and human actions included in the development of the accident progression sequences and the justification for their inclusion or exclusion from the accident progression analysis *(d)* the analysis of factors influencing containment challenges and containment capability, as appropriate for the level of detail of the analysis *(e)* the basis for the containment capacity analysis including the identification of containment failure location(s), if applicable *(f)* the accident progression analysis sequences included in the containment event trees *(g)* the basis for parameter estimates *(h)* the model integration process including the results of the quantification, and identification of risk-significant contributors to LERF *(i)* the uncertainty distribution for the total LERF	
LE-G2	DOCUMENT the risk-significant contributors (e.g., initiating events, accident sequences, basic events) to LERF in the PRA results summary. DESCRIBE risk-significant accident sequences or functional failure groups in accordance with the definitions provided in Section 1-2.2. DOCUMENT the relative contribution of contributors (i.e., PDSs, accident progression sequences, phenomena, containment challenges, containment failure modes)	
LE-G3	DOCUMENT the sources of model uncertainty, related assumptions, and reasonable alternatives (as identified in SR LE-F3) associated with the LERF Analysis.	
LE-G4	DOCUMENT limitations in the LERF Analysis that would impact applications.	

Table 2-2.8-9 LERF Contributors to Be Considered

LERF Contributor	Containment Design				
	Large Dry Subatmospheric	Ice Condenser	BWR Mark I	BWR Mark II	BWR Mark III
Containment isolation failure	X	X	X	X	X [Note (1)]
Containment Bypass					
(a) ISLOCA	X	X	X	X	X
(b) SGTR	X	X	. . .	. . .	. . .
(c) Induced SGTR	X	X	. . .	. . .	. . .
Energetic containment failures					
(a) HPME	X	X	X	X	X
(b) Hydrogen combustion	. . .	X	X [Note (3)]	X [Note (3)]	X
(c) Core debris impingement	[Note (2)]	X	X	X	. . .
Steam explosion [Note (4)]	. . .	. . .	X	X	X
Shell melt-through	. . .	. . .	X (if applicable)	X (if applicable)	. . .
Pressure suppression bypass [Note (5)]	. . .	X	X	X	X
RPV and/or containment venting	X (if applicable)	X (if applicable)	X	X	X
Isolation condenser tube rupture	. . .	X (if applicable)	. . .	. . .	
Vacuum breaker failure	. . .	. . .	X	X	X
Hydrodynamic loads under severe accident conditions	. . .	. . .	X	X	X
Containment flooding	. . .	. . .	X	X	. . .
In-vessel recovery	X	X	X	X	X
ATWS-induced failure	. . .	. . .	X	X	X

GENERAL NOTE: Combinations of contributors should also be analyzed where appropriate. For example, in a BWR Mark I or II, the combination of containment flooding and containment venting should be analyzed.

NOTES:
(1) drywell (DW) isolation failure
(2) applicable to steel shell designs only
(3) during de-inerted operation only
(4) steam explosion challenges are of low probability for PWRs
(5) ice bed bypass for ice condensers and suppression pool bypass for BWR

NONMANDATORY APPENDIX 2-A
EXPLANATORY NOTES REGARDING APPLICATION OF THE PART 2 SUPPORTING REQUIREMENTS

2-A.1 ORGANIZATION AND CONTENT

This Nonmandatory Appendix (NMA) provides notes and general explanatory material tied to specific SRs as stated in Part 2 of this Standard. The material contained in this Appendix is nonmandatory and, as such, does not establish new requirements: rather, the material is intended to clarify the intent of an SR, explain jargon that might be used in an SR, and/or provide examples of analysis approaches that would meet the intent of the SR.

The explanatory material, presented in Section 2-A.2, is organized by technical element and then by SR number. For example, Table 2-A.2.1-2 provides explanatory material for the Initiating Events SRs. All of the commentary is provided at the SR level and, thus, there are no tables for the HLRs in this appendix. Note that not all SRs include explanatory material. The SRs that do not have additional explanatory material are indicated with "No commentary provided."

The goal of the notes and commentary in this NMA to Part 2 is to ensure that analysts are apprised of certain known characteristics, challenges, and issues associated with the Level 1 PRA model. While some of the discussion includes "primer-like" information, the language herein should not be viewed as prescriptive. The analyst should not interpret this Appendix as limiting flexibility in the performance of the technical analyses or in the application of expert judgment. A broad range of tools, techniques, implicit/explicit analyses, and judgment may be required to address the diverse modeling required. Comprehensive documentation of the data and technical bases for the analyses modeling decisions is a critical part of a Level 1 internal-events PRA.

2-A.2 COMMENTARY TO INTERNAL-EVENTS PRA TECHNICAL ELEMENTS AND REQUIREMENTS

2-A.2.1 COMMENTARY TO INITIATING EVENT ANALYSIS (IE)

Table 2-A.2.1-1 Commentary to High Level Requirements for Internal Initiating Event Analysis (IE)

Designator	Commentary
HLR-IE-A	No commentary provided.
HLR-IE-B	No commentary provided.
HLR-IE-C	No commentary provided.
HLR-IE-D	No commentary provided.

Table 2-A.2.1-2 Commentary to Supporting Requirements for HLR-IE-A

Index No. IE-A	Commentary
IE-A1	No commentary provided.
IE-A2	No commentary provided.
IE-A3	No commentary provided.
IE-A4	No commentary provided.
IE-A5	No commentary provided.
IE-A6	No commentary provided.
IE-A7	No commentary provided.
IE-A8	No commentary provided.
IE-A9	No commentary provided.
IE-A10	No commentary provided.
IE-A11	No commentary provided.

Table 2-A.2.1-3 Commentary to Supporting Requirements for HLR-IE-B

Index No. IE-B	Commentary
IE-B1	No commentary provided.
IE-B2	No commentary provided.
IE-B3	No commentary provided.
IE-B4	No commentary provided.
IE-B5	No commentary provided.

Table 2-A.2.1-4 Commentary to Supporting Requirements for HLR-IE-C

<table>
<tr><th>Index No. IE-C</th><th>Commentary</th></tr>
<tr><td>IE-C1</td><td>No commentary provided.</td></tr>
<tr><td>IE-C2</td><td>No commentary provided.</td></tr>
<tr><td>IE-C3</td><td>No commentary provided.</td></tr>
<tr><td>IE-C4</td><td>No commentary provided.</td></tr>
<tr><td>IE-C5</td><td>For the computation of annual average CDF/LERF (i.e., for comparison to Reg. Guide 1.174 [2-A-24] quantitative acceptance guidelines), the appropriate units for initiating-event frequency are events per calendar year, commonly expressed as events per reactor-year, where a reactor-year is one full calendar year of experience for one reactor. However, when determining total annual plant CDF (or LERF), which includes contributions from events occurring during power operation as well as during other plant operating states, the calculation of the contribution for each operating state must address the fraction of the year that the plant is in that operating state. Two examples follow:

(a) Loss of Bus Initiating Event. A loss of bus initiating event can be computed by annualizing the hourly failure rate of the bus and associated breakers, relays, and so on, that could lead to loss of power on the bus during the time the plant is at-power. For example, for the bus itself, the initiating-event frequency over a full year would be calculated as

$$f_{bus\text{-}8,760} = \lambda_{bus} * H_{year}$$
where

f_{bus}-8,760 = frequency of loss of bus over a full 8,760-hr year

H_{year} = hours in 1 calendar year or reactor-year, 8,760 hr/yr

λ_{bus} = failure rate of bus per hour, for example, 1.0E-7/hr

However, to calculate CDF (or LERF) for events at-power only (i.e., for the scope of PRA covered by this Standard), it is necessary to adjust for the fraction of time the plant is at-power. Thus, the result obtained from the above equation needs to be multiplied by an additional term, say $F_{at\text{-}power}$

where

$F_{at\text{-}power}$ = fraction of year that, on average, the plant is at-power, for example, 90%

Thus,

$F_{bus\ at\text{-}power}$ = 1.0E-7/hr × 8,760 hr/yr × 0.90 = 7.9E-4/reactor-year

(b) Turbine Trip Initiating Event. Some initiating events, such as a turbine trip, may be computed based on plant-specific experience. In this case, the number of events classified as turbine trip events is in the numerator, and the number of applicable calendar years of operation is in the denominator. The fraction of time at-power is implicitly included in the numerator because the turbine trip experience is limited to at-power experience by the nature of the event.

Thus,

$$f_{TT} = N_{TT}/Y_{OP}$$
where

f_{TT} = frequency of turbine trip events per reactor-year

N_{TT} = number of events classified as turbine trip events (e.g., 27 events)

Y_{OP} = number of applicable calendar years of plant operation, regardless of operating mode (e.g., 23 yrs)

Therefore,

$$f_{TT} = 27 \text{ events} / 23 \text{ yrs} = 1.2 / \text{reactor–year}$$
The number of applicable calendar years should be based on the time period of the event data being used and may exclude unusual periods of nonoperation (i.e., if the plant were in an extended forced shutdown).</td></tr>
</table>

Table 2-A.2.1-4 Commentary to Supporting Requirements for HLR-IE-C (Cont'd)

Index No. IE-C	Commentary
IE-C5 (Cont'd)	For some applications, such as configuration risk management or analyses that compare specific risks during different modes of operation, it may be appropriate to use initiating-event frequencies that do not include the fraction of time in the operating state. In these cases, the initiating-event frequency should be per unit of time (i.e., per hour or per year). For at-power operation, this basis is sometimes referred to as per reactor-critical-year (i.e., assuming that the reactor operated continuously for a year). On a more general basis, it could be considered to be per reactor-operating-state-year. In the loss of bus initiating-event example above, the term $F_{\text{at-power}}$ would not be included in the computation of initiating-event frequency for these kinds of applications. In the turbine trip initiating-event example above, the value must be adjusted by dividing f_{TT} by $F_{\text{at-power}}$.
IE-C6	Initiating events involving a complicated shutdown cannot be screened out. A complicated shutdown is performed as a result of a degraded condition (e.g., initiating event) requiring additional operator actions beyond those of a normal shutdown or involves the unavailability of one or more systems normally used to safely shut down the reactor.
IE-C7	No commentary provided.
IE-C8	Some initiating events are amenable to fault-tree modeling as the appropriate way to quantify them. These initiating events, usually support-system failure events, are highly dependent on plant-specific design features.
IE-C9	No commentary provided.
IE-C10	No commentary provided.
IE-C11	No commentary provided.
IE-C12	No commentary provided.
IE-C13	No commentary provided.
IE-C14	No commentary provided.
IE-C15	No commentary provided.

Table 2-A.2.1-5 Commentary to Supporting Requirements for HLR-IE-D

Index No. IE-D	Commentary
IE-D1	An example of one method to satisfy this SR is a cross-reference identifying each SR and where it is addressed in the documentation. This example of a documentation method facilitates PRA applications, upgrades, and peer reviews.
IE-D2	One potentially acceptable method is described in NUREG-1855 [2-A-22].

2-A.2.2 COMMENTARY TO ACCIDENT SEQUENCE ANALYSIS (AS)

Table 2-A.2.2-1 Commentary to High Level Requirements for Accident Sequence Analysis (AS)

Designator	Commentary
HLR-AS-A	No commentary provided.
HLR-AS-B	No commentary provided.
HLR-AS-C	No commentary provided.

Table 2-A.2.2-2 Commentary to Supporting Requirements for HLR-AS-A

Index No. AS-A	Commentary
AS-A1	No commentary provided.
AS-A2	SRs AS-A2, AS-A3, and AS-A4 define the model in terms of how the plant works but do not address what the model should include. Modeling details are addressed in SRs AS-A5, AS-A6, AS-A7, AS-A8, AS-A9, AS-A10, and AS-11.
AS-A3	SRs AS-A2, AS-A3, and AS-A4 define the model in terms of how the plant works but do not address what the model should include. Modeling details are addressed in SRs AS-A5, AS-A6, AS-A7, AS-A8, AS-A9, AS-A10, and AS-11.
AS-A4	SRs AS-A2, AS-A3, and AS-A4 define the model in terms of how the plant works but do not address what the model should include. Modeling details are addressed in SRs AS-A5, AS-A6, AS-A7, AS-A8, AS-A9, AS-A10, and AS-11. The intent of SR AS-A4 is not to address specific procedures but rather to identify, at a functional level, what is required of the operators for success.
AS-A5	No commentary provided.
AS-A6	No commentary provided.
AS-A7	No commentary provided.
AS-A8	No commentary provided.
AS-A9	No commentary provided.
AS-A10	No commentary provided.
AS-A11	No commentary provided.
AS-A12	No commentary provided.

Table 2-A.2.2-3 Commentary to Supporting Requirements for HLR-AS-B

Index No. AS-B	Commentary
AS-B1	No commentary provided.
AS-B2	No commentary provided.
AS-B3	No commentary provided.
AS-B4	No commentary provided.
AS-B5	No commentary provided.
AS-B6	No commentary provided.
AS-B7	No commentary provided.

Table 2-A.2.2-4 Commentary to Supporting Requirements for HLR-AS-C

Index No. AS-C	Capability Category I	Capability Category II
AS-C1	An example of one method to satisfy this SR is a cross-reference identifying each SR and where it is addressed in the documentation. This documentation method facilitates PRA applications, upgrades, and peer reviews.	
AS-C2	One potentially acceptable method is described in NUREG-1855 [2-A-22].	

2-A.2.3 COMMENTARY TO SUCCESS CRITERIA (SC)

Table 2-A.2.3-1 Commentary to High Level Requirements for Success Criteria (SC)

Designator	Commentary
HLR-SC-A	No commentary provided.
HLR-SC-B	No commentary provided.

Table 2-A.2.3-2 Commentary to Supporting Requirements for HLR-SC-A

Index No. SC-A	Commentary	
SC-A1	No commentary provided.	
SC-A2	Pages 3 through 8 of reference [2-A-2] used the following simplified definitions of core damage to avoid the need for "detailed thermal-hydraulic calculations beyond the scope and resources of the work." For BWRs, "the core is considered to be in a damaged state when the reactor water level is less than 2 ft above the bottom of the active fuel." For PWRs, "the core is considered to be in a damaged state once the top of the active fuel assemblies is uncovered."	Examples of measures for core damage for non-ATWS scenarios include *(a)* collapsed liquid level less than one-third core height or code-predicted peak core temperature >2,500°F (BWR) *(b)* Collapsed liquid level below top of active fuel for a prolonged period; or code-predicted peak core temperature >2,200°F using a code with simplified (e.g., single-node core model, lumped parameter) core modeling (PWR) The "peak core temperature" in this example refers to post-initiator conditions.
SC-A3	Requirements for specifying success criteria appear under HLRs for other technical elements as well (e.g., HLR-AS-A, HLR-SY-A). These requirements are intended to be complementary, not duplicative. For example, for accident sequences, SRs AS-A2, SC-A3, SC-A4 (if applicable), AS-A3, and AS-A4 are intended to be used together to specify the set of systems and human actions necessary to meet the key safety function success criteria.	
SC-A4	No commentary provided.	
SC-A5	No commentary provided.	
SC-A6	No commentary provided.	
SC-A7	No commentary provided.	
SC-A8	No commentary provided.	

Table 2-A.2.3-3 Commentary to Supporting Requirements for HLR-SC-B

Index No. SC-B	Commentary
SC-B1	No commentary provided.
SC-B2	No commentary provided.
SC-B3	No commentary provided.
SC-B4	No commentary provided.
SC-B5	No commentary provided.
SC-B6	No commentary provided.

Table 2-A.2.3-4 Commentary to Supporting Requirements for HLR-SC-C

Index No. SC-C	Commentary
SC-C1	An example of one method to satisfy this SR is a cross-reference identifying each SR and where it is addressed in the documentation. This documentation method facilitates PRA applications, upgrades, and peer reviews.
SC-C2	One potentially acceptable method is described in NUREG-1855 [2-A-22].

2-A.2.4 COMMENTARY TO SYSTEMS ANALYSIS (SY)

Table 2-A.2.4-1 Commentary to High Level Requirements for Systems Analysis (SY)

Designator	Commentary
HLR-SY-A	No commentary provided.
HLR-SY-B	No commentary provided.
HLR-SY-C	No commentary provided.

Table 2-A.2.4-2 Commentary to Supporting Requirements for HLR-SY-A

Index No. SY-A	Commentary	
SY-A1	No commentary provided.	
SY-A2	No commentary provided.	
SY-A3	No commentary provided.	
SY-A4	No commentary provided.	
SY-A5	To ASSESS the effects of alternate system alignments, the potential impact on CDF and applications should be considered. For example, the potential impact on CDF and applications can be considered quantitatively, by modeling the alternate alignments that are used regularly, or qualitatively, by discussing the differences between the alignments, the time in the alternate alignments, and the perceived impact, including support system dependencies. As long as the potential impacts of the alternate alignments are identified, the actual numerical impact on CDF is not required to meet CC-I.	No commentary provided.
SY-A6	No commentary provided.	
SY-A7	No commentary provided.	
SY-A8	No commentary provided.	
SY-A9	No commentary provided.	
SY-A10	No commentary provided.	
SY-A11	No commentary provided.	
SY-A12	No commentary provided.	
SY-A13	No commentary provided.	
SY-A14	No commentary provided.	
SY-A15	No commentary provided.	
SY-A16	No commentary provided.	
SY-A17	No commentary provided.	
SY-A18	No commentary provided.	
SY-A19	No commentary provided.	
SY-A20	No commentary provided.	
SY-A21	No commentary provided.	
SY-A22	No commentary provided.	
SY-A23	No commentary provided.	
SY-A24	No commentary provided.	
SY-A25	No commentary provided.	

Table 2-A.2.4-3 Commentary to Supporting Requirements for HLR-SY-B

Index No. SY-B	Commentary
SY-B1	One potentially acceptable method is described in NUREG/CR-5485 [2-A-3]. One potentially acceptable method is described in NUREG/CR-5485 [2-A-3].
SY-B2	No commentary provided.
SY-B3	No commentary provided.
SY-B4	Dependency on support or interfacing systems may be modeled in one of the following ways: *(a)* for the fault-tree linking approach, model the dependencies as a link to the appropriate event or gate in the support-system fault tree *(b)* for the linked event-tree approach, USE event-tree logic rules or calculate a probability for each split fraction conditional on the scenario definition
SY-B5	No commentary provided.
SY-B6	No commentary provided.
SY-B7	The information collected from plant walkdowns are one source of information regarding spatial/environmental hazards, for resolution of spatial/environmental issues or evaluation of the impacts of such hazards.
SY-B8	No commentary provided.
SY-B9	No commentary provided.
SY-B10	No commentary provided.
SY-B11	No commentary provided.
SY-B12	No commentary provided.
SY-B13	No commentary provided.
SY-B14	No commentary provided.

Table 2-A.2.4-4 Commentary to Supporting Requirements for HLR-SY-C

Index No. SY-C	Commentary
SY-C1	An example of one method to satisfy this SR is a cross-reference identifying each SR and where it is addressed in the documentation. This documentation method facilitates PRA applications, upgrades, and peer reviews.
SY-C2	One potentially acceptable method is described in NUREG-1855 [2-A-22].

2-A.2.5 COMMENTARY TO HUMAN RELIABILITY ANALYSIS (HR)

Reference [2-A-23] provides useful background information for Human Reliability Analysis.

Table 2-A.2.5-1 Commentary to High Level Requirements for Human Reliability Analysis (HR)

Designator	Commentary
Pre-Initiator HRA	
HLR-HR-A	No commentary provided.
HLR-HR-B	No commentary provided.
HLR-HR-C	No commentary provided.
HLR-HR-D	No commentary provided.
Post-Initiator HRA	
HLR-HR-E	No commentary provided.
HLR-HR-F	No commentary provided.
HLR-HR-G	No commentary provided.
HLR-HR-H	No commentary provided.
Pre- and Post-Initiator HRA	
HLR-HR-I	No commentary provided.

Table 2-A.2.5-2 Commentary to Supporting Requirements for HLR-HR-A

Index No. HR-A	Commentary
HR-A1	No commentary provided.
HR-A2	No commentary provided.
HR-A3	No commentary provided.
HR-A4	No commentary provided.

Table 2-A.2.5-3 Commentary to Supporting Requirements for HLR-HR-B

Index No. HR-B	Commentary
HR-B1	No commentary provided.
HR-B2	No commentary provided.

Table 2-A.2.5-4 Commentary to Supporting Requirements for HLR-HR-C

Index No. HR-C	Commentary
HR-C1	No commentary provided.
HR-C2	No commentary provided.
HR-C3	No commentary provided.

Table 2-A.2.5-5 Commentary to Supporting Requirements for HLR-HR-D

Index No. HR-D	Commentary
HR-D1	Acceptable methods include THERP [2-A-4] and ASEP [2-A-5].
HR-D2	No commentary provided.
HR-D3	No commentary provided. The quality of the human-machine interface takes into account adherence to human factors guidelines (see NUREG-0700 [2-A-18]) and results of any quantitative evaluations of performance per functional requirements.
HR-D4	No commentary provided.
HR-D5	When considering multiple human actions in the same accident sequence or cutset, a minimum joint HEP should be identified and justified. One approach for establishing minimum HEP values is provided in EPRI 1021081 [2-A-20] or the updated version, EPRI 3002003150 [2-A-25]. NUREG-1792 [2-A-21] also provides a discussion of the minimum joint HEP.
HR-D6	No commentary provided.

Table 2-A.2.5-6 Commentary to Supporting Requirements for HLR-HR-E

Index No. HR-E	Commentary
HR-E1	No commentary provided.
HR-E2	No commentary provided.
HR-E3	No commentary provided.
HR-E4	No commentary provided.
HR-E5	No commentary provided.

Table 2-A.2.5-7 Commentary to Supporting Requirements for HLR-HR-F

Index No. HR-F	Commentary
HR-F1	No commentary provided.
HR-F2	No commentary provided.

Table 2-A.2.5-8 Commentary to Supporting Requirements for HLR-HR-G

Index No. HR-G	Commentary
HR-G1	No commentary provided.
HR-G2	No commentary provided.
HR-G3	The ASEP Approach [2-A-5] may be acceptable for the CC-I requirement. / No commentary provided.
HR-G4	No commentary provided.
HR-G5	No commentary provided.
HR-G6	No commentary provided.
HR-G7	When considering multiple human actions in the same accident sequence or cutset, a minimum joint HEP is identified and justified. This SR is not meant to imply that a single value is to be used as a minimum HEP for all situations. Instead, a minimum joint HEP is set as a threshold for which cutset or accident sequence-specific justification is not required. Lower joint HEPs may be used if justified based on the context of the cutset or accident sequence (e.g., consider the impact of changing plant state, additional cues, additional resources, applicability of procedures and training). Approaches for establishing minimum joint HEP values are discussed in EPRI 1021081 [2-A-20] or the updated version, EPRI 3002003150 [2-A-25], and NUREG-1792 [2-A-21]. A sensitivity study for the defined minimum joint HEP may be performed to assess the impact on the CDF or LERF results, importance measures, or applications.
HR-G8	No commentary provided.
HR-G9	The suggestions in NUREG/CR-4550 [2-A-2] provide examples of how lowest acceptable limits may be applicable to different contexts. Examples of appropriate technical justification for use of a lower joint HEP can include contextual considerations that might indicate very low dependence or independence between human actions, such as timing, changing plant state, additional cues, additional resources, the applicability of procedures, and training. Such justification considers the specific human-action combinations in conjunction with specific accident sequences or cutsets. A particular HFE combination can be excluded if it can be shown to have no impact on risk, based on applicable evaluation of each cutset or accident sequence with that combination. This SR is intended to support an assessment for dependency risk impacts to ensure the driving factors are adequately captured in the PRA model results. Examples of factors that support of a reasonable technical justification can be found in EPRI 3002003150 [2-A-25].
HR-G10	No commentary provided.

Table 2-A.2.5-9 Commentary to Supporting Requirements for HLR-HR-H

Index No. HR-H	Commentary
HR-H1	No commentary provided.
HR-H2	No commentary provided.
HR-H3	No commentary provided.
HR-H4	No commentary provided.

Table 2-A.2.5-10 Commentary to Supporting Requirements for HLR-HR-I

Index No. HR-I	Commentary
HR-I1	An example of one method to satisfy this SR is a cross-reference identifying each SR and where it is addressed in the documentation. This documentation method facilitates PRA applications, upgrades, and peer reviews.
HR-I2	One potentially acceptable method is described in NUREG-1855 [2-A-22].

2-A.2.6 COMMENTARY TO DATA ANALYSIS (DA)

Table 2-A.2.6-1 Commentary to High Level Requirements for Data Analysis (DA)

Designator	Commentary
HLR-DA-A	No commentary provided.
HLR-DA-B	No commentary provided.
HLR-DA-C	No commentary provided.
HLR-DA-D	No commentary provided.
HLR-DA-E	No commentary provided.

Table 2-A.2.6-2 Commentary to Supporting Requirements for HLR-DA-A

Index No. DA-A	Commentary
DA-A1	No commentary provided.
DA-A2	No commentary provided.
DA-A3	Examples include *(a)* $1-e^{-\lambda T} \cong \lambda T$ when $\lambda T < 0.1$ for failure to continue running over a component mission time, T, with a constant failure rate, λ *(b)* $(\lambda\tau)/2$ for a periodically tested standby component subject to a standby failure rate of λ and a testing interval of τ *(c)* q for a failure on demand, based on a failure on demand probability "q" that does not consider testing interval
DA-A4	No commentary provided.
DA-A5	No commentary provided.

Table 2-A.2.6-3 Commentary to Supporting Requirements for HLR-DA-B

Index No. DA-B	Commentary
DA-B1	No commentary provided.
DA-B2	No commentary provided.

Table 2-A.2.6-4 Commentary to Supporting Requirements for HLR-DA-C

Index No. DA-C	Commentary
DA-C1	Examples of parameter estimates and associated sources include *(a)* component failure rates and probabilities: NUREG/CR-4639 [2-A-6], NUREG/CR-4550 [2-A-2], NUREG-1715 [2-A-17], NUREG/CR-6928 [2-A-16] *(b)* CCFs: NUREG/CR-5497 [2-A-7], NUREG/CR-6268 [2-A-8] *(c)* AC off-site power recovery: NUREG/CR-5496 [2-A-9], NUREG/CR-5032 [2-A-10] *(d)* component recovery See NUREG/CR-6823 [2-A-1] for a listing of additional data sources.
DA-C2	No commentary provided.
DA-C3	No commentary provided.
DA-C4	No commentary provided.
DA-C5	No commentary provided.
DA-C6	No commentary provided.
DA-C7	No commentary provided.
DA-C8	No commentary provided.
DA-C9	No commentary provided.
DA-C10	No commentary provided.
DA-C11	No commentary provided.
DA-C12	No commentary provided.
DA-C13	No commentary provided.
DA-C14	No commentary provided.
DA-C15	No commentary provided.
DA-C16	No commentary provided.

Table 2-A.2.6-5 Commentary to Supporting Requirements for HLR-DA-D

Index No. DA-D	Commentary	
DA-D1	No commentary provided.	
DA-D2	No commentary provided.	
DA-D3	No commentary provided.	
DA-D4	No commentary provided.	
DA-D5	The Beta-factor screening approach in NUREG/CR-5485 [2-A-3] may be acceptable for the CC-I requirement.	No commentary provided.
DA-D6	No commentary provided.	
DA-D7	No commentary provided.	
DA-D8	No commentary provided.	

Table 2-A.2.6-6 Commentary to Supporting Requirements for HLR-DA-E

Index No. DA-E	Commentary
DA-E1	An example of one method to satisfy this SR is a cross-reference identifying each SR and where it is addressed in the documentation. This documentation method facilitates PRA applications, upgrades, and peer reviews.
DA-E2	One potentially acceptable method is described in NUREG-1855 [2-A-22].

2-A.2.7 COMMENTARY TO QUANTIFICATION (QU)

Table 2-A. 2.7-1 Commentary to High Level Requirements for Quantification (QU)

Designator	Commentary
HLR-QU-A	No commentary provided.
HLR-QU-B	No commentary provided.
HLR-QU-C	No commentary provided.
HLR-QU-D	No commentary provided.
HLR-QU-E	No commentary provided.
HLR-QU-F	No commentary provided.

Table 2-A.2.7-2 Commentary to Supporting Requirements for HLR-QU-A

Index No. QU-A	Commentary
QU-A1	No commentary provided.
QU-A2	No commentary provided.
QU-A3	No commentary provided. It has been found that risk-significant cutsets contributing to ISLOCA frequency that involve rupture of multiple valves, for example, can exhibit a significant impact of state-of-knowledge correlation (see [2-A-11]).
QU-A4	No commentary provided.
QU-A5	No commentary provided.
QU-A6	No commentary provided.

Table 2-A.2.7-3 Commentary to Supporting Requirements for HLR-QU-B

Index No. QU-B	Commentary
QU-B1	No commentary provided.
QU-B2	No commentary provided.
QU-B3	No commentary provided.
QU-B4	Using the rare-event approximation (i.e., summing the cutsets to obtain the CDF) is appropriate only if the basic event probabilities are small. Other solution methods such as the minimal cutset upper bound are generally more appropriate and sufficient for internal-event models. Although less sensitive to nonrare events, some of these other methods may also assume that the probabilities are small. In situations where there are a significant number of events with high probability, additional evaluation may be appropriate to determine that the results are suitable for the given application.
QU-B5	Guidance for breaking logic loops is provided in NUREG/CR-2728 [2-A-12].
QU-B6	No commentary provided.
QU-B7	No commentary provided.
QU-B8	No commentary provided.
QU-B9	No commentary provided.
QU-B10	No commentary provided.

Table 2-A.2.7-4 Commentary to Supporting Requirements for HLR-QU-C

Index No. QU-C	Commentary
QU-C1	No commentary provided.
QU-C2	No commentary provided.
QU-C3	No commentary provided.

Table 2-A.2.7-5 Commentary to Supporting Requirements for HLR-QU-D

Index No. QU-D	Commentary
QU-D1	No commentary provided.
QU-D2	No commentary provided.
QU-D3	No commentary provided.
QU-D4	No commentary provided.
QU-D5	No commentary provided.
QU-D6	No commentary provided.
QU-D7	No commentary provided.
QU-D8	No commentary provided.

Table 2-A.2.7-6 Commentary to Supporting Requirements for HLR-QU-E

Index No. QU-E	Commentary
QU-E1	The impact on the PRA of known model uncertainties, simplifying assumptions, and screened-out initiating events need to be identified and their potential impact discussed. The impact on the PRA includes the impact on the individual technical elements of the PRA (e.g., Accident Sequences, Data, Human Reliability Analysis), not just the impact on the calculated CDF/LERF. Possible effects include introduction of a new basic event, changes to basic event probabilities, changes in success criteria, and so on.
QU-E2	No commentary provided.

Table 2-A.2.7-7 Commentary to Supporting Requirements for HLR-QU-F

Index No. QU-F	Commentary
QU-F1	An example of one method to satisfy this SR is a cross-reference identifying each SR and where it is addressed in the documentation. This documentation method facilitates PRA applications, upgrades, and peer reviews.
QU-F2	No commentary provided.
QU-F3	One potentially acceptable method is described in NUREG-1855 [2-A-22].
QU-F4	No commentary provided.

2-A.2.8 COMMENTARY TO LERF ANALYSIS (LE)

Table 2-A.2.8-1 Commentary to High Level Requirements for LERF Analysis (LE)

Designator	Commentary
HLR-LE-A	No commentary provided.
HLR-LE-B	No commentary provided.
HLR-LE-C	No commentary provided.
HLR-LE-D	No commentary provided.
HLR-LE-E	No commentary provided.
HLR-LE-F	No commentary provided.
HLR-LE-G	No commentary provided.

Table 2-A.2.8-2 Commentary to Supporting Requirements for HLR-LE-A

Index No. LE-A	Commentary
LE-A1	No commentary provided.
LE-A2	References [2-A-13] and [2-A-14] provide example lists of typical accident sequence characteristics that can influence LERF.
LE-A3	No commentary provided.
LE-A4	No commentary provided.
LE-A5	No commentary provided.

Table 2-A.2.8-3 Commentary to Supporting Requirements for HLR-LE-B

Index No. LE-B	Commentary	
LE-B1	The methodology and data contained in NUREG/CR-6595 [2-A-15] may be acceptable for the CC-I requirement.	NUREG/CR-6595 [2-A-15] may be used to identify LERF contributors from Table 2-2.8-9 for applicability. In addition, lessons learned from Fukushima regarding scenarios with hydrogen leakage to the auxiliary building should also be considered.
LE-B2	The methodology and data contained in NUREG/CR-6595 [2-A-15] may be an acceptable approach for the CC-I requirement.	No commentary provided.
LE-B3	No commentary provided.	

Table 2-A.2.8-4 Commentary to Supporting Requirements for HLR-LE-C

Index No. LE-C	Commentary	
LE-C1	The methodology and data contained in NUREG/CR-6595 [2-A-15] may be an acceptable approach for the CC-I requirement.	NUREG/CR-6595, App. A [2-A-15] and NUREG-1935 [2-A-19] provide discussion and examples of LERF source terms.
LE-C2	The methodology and data contained in NUREG/CR-6595 [2-A-15] may be an acceptable approach for the CC-I requirement.	No commentary provided.
LE-C3	No commentary provided.	
LE-C4	The methodology and data contained in NUREG/CR-6595 [2-A-15] may be an acceptable approach for the CC-I requirement.	No commentary provided.
LE-C5	No commentary provided.	
LE-C6	No commentary provided.	
LE-C7	No commentary provided.	
LE-C8	No commentary provided.	
LE-C9	The methodology and data contained in NUREG/CR-6595 [2-A-15] may be an acceptable approach for the CC-I requirement.	No commentary provided.
LE-C10	No commentary provided.	
LE-C11	No commentary provided.	
LE-C12	The methodology and data contained in NUREG/CR-6595 [2-A-15] may be an acceptable approach for the CC-I requirement.	No commentary provided.

Table 2-A.2.8-5 Commentary to Supporting Requirements for HLR-LE-D

Index No. LE-D	Commentary	
LE-D1	The methodology and data contained in NUREG/CR-6595 [2-A-15] may be an acceptable approach for the CC-I requirement.	Quasi-static containment capability evaluations are acceptable unless hydrogen concentrations are expected to result in potential detonations: include such considerations for small volume containments (e.g., ice-condenser type).
LE-D2	The methodology and data contained in NUREG/CR-6595 [2-A-15] may be an acceptable approach for the CC-I requirement.	No commentary provided.
LE-D3	Containment failures below ground level may not be a large early release even if the timing is early. Such failures may arise as a result of failures in the basemat region. Containment failures that result in impacts on structures other than containment (e.g., loss of hydrogen control) should be considered. The methodology and data contained in NUREG/CR-6595 [2-A-15] may be an acceptable approach for the CC-I requirement.	Containment failures below ground level may not be a large early release even if the timing is early. Such failures may arise as a result of failures in the basemat region. Containment failures that result in impacts on structures other than containment (e.g., loss of hydrogen control) should be considered.
LE-D4	No commentary provided.	
LE-D5	No commentary provided.	
LE-D6	The methodology and data contained in NUREG/CR-6595 [2-A-15] may be an acceptable approach for the CC-I requirement.	When justifying assumptions and key inputs, use of reasonably bounding assumptions, or performance of sensitivity studies indicating low sensitivity to changes in the range in question is acceptable. An acceptable approach is one that arrives at plant-specific split fractions by selecting the steam generator tube conditional failure probabilities based on current industry guidance for induced steam generator failure of similarly designed steam generators and loop piping.
LE-D7	No commentary provided.	

Table 2-A.2.8-6 Commentary to Supporting Requirements for HLR-LE-E

Index No. LE-E	Commentary	
LE-E1	No commentary provided.	
LE-E2	The methodology and data contained in NUREG/CR-6595 [2-A-15] may be an acceptable approach for the CC-I requirement.	No commentary provided.
LE-E3	The methodology and data contained in NUREG/CR-6595 [2-A-15] may be an acceptable approach for the CC-I requirement.	No commentary provided.
LE-E4	The SRs referenced in these tables are written in CDF language. Pursuant to this requirement, the applicable Quantification requirements in HLR-QU-A should be interpreted based on the approach taken for the LERF model. For example, SR QU-A2 addresses the calculation of point estimate/mean CDF. Pursuant to this requirement, the application of SR QU-A2 would apply to the quantification of point estimate/mean LERF.	

Table 2-A.2.8-7 Commentary to Supporting Requirements for HLR-LE-F

Index No. LE-F	Commentary	
LE-F1	No commentary provided.	
LE-F2	The SRs referenced in Table 2-2.7-5 (HLR-QU-D) are written in CDF language. The applicable requirements of HLR-QU-D and HLR-QU-E should be interpreted based on LERF, including characterizing the sources of model uncertainty and related assumptions associated with the applicable contributors from Table 2-2.8-9. For example, SR QU-D6 addresses the risk-significant contributors to CDF. Under this requirement, the contributors would be identified based on their contribution to LERF.	The SRs referenced in Table 2-2.7-5 (HLR-QU-D) are written in CDF language. The applicable requirements of HLR-QU-D and HLR-QU-E should be interpreted based on LERF, including characterizing the sources of model uncertainty and related assumptions associated with the applicable contributors from Table 2-2.8-9. For example, SR QU-D6 addresses the risk-significant contributors to CDF. Under this requirement, the contributors would be identified based on their contribution to LERF.
LE-F3	The SRs referenced in this table are written in CDF language. The applicable requirements of HLR-QU-D and HLR-QU-E should be interpreted based on LERF, including characterizing the sources of model uncertainty and related assumptions associated with the applicable contributors from Table 2-2.8-9. For example, SR QU-D6 addresses the risk-significant contributors to CDF. Pursuant to this requirement, the contributors would be identified based on their contribution to LERF.	The SRs referenced in this table are written in CDF language. The applicable requirements of HLR-QU-D and HLR-QU-E should be interpreted based on LERF, including characterizing the sources of model uncertainty and related assumptions associated with the applicable contributors from Table 2-2.8-9. For example, SR QU-D6 addresses the risk-significant contributors to CDF. Pursuant to this requirement, the contributors would be identified based on their contribution to LERF.

Table 2-A.2.8-8 Commentary to Supporting Requirements for HLR-LE-G

Index No. LE-G	Commentary
LE-G1	An example of one method to satisfy this SR is a cross-reference identifying each SR and where it is addressed in the documentation. This documentation method facilitates PRA applications, upgrades, and peer reviews.
LE-G2	No commentary provided.
LE-G3	One potentially acceptable method is described in NUREG-1855 [2-A-22].
LE-G4	No commentary provided.

2-A.3 REFERENCES

The following is a list of publications referenced in this Appendix.

[2-A-1] NUREG/CR-6823 and SAND2003-3348P, "Handbook of Parameter Estimation for Probabilistic Risk Assessment," C. L. Atwood et al., Sandia National Laboratories (SNL), September 2003; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-2] NUREG/CR-4550 and SAND86-2084, Vol. 1, Rev. 1, "Analysis of Core Damage Frequency: Internal Events Methodology," D. M. Ericson et al., Sandia National Laboratories (SNL), January 1990; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-3] NUREG/CR-5485 and INEEL/EXT-97-01327, "Guidelines on Modeling Common-Cause Failures in Probabilistic Risk Assessment," F. M. Marshall, A. Mosleh, and D. M. Rasmuson, Idaho National Engineering and Environmental Laboratory (INEEL), November 20, 1998; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-4] NUREG/CR-1278 and SAND80-0200, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications," A. D. Swain and H. E. Guttmann, Sandia National Laboratories (SNL) (Technique for Human Error Rate Prediction), August 1983; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-5] NUREG/CR-4772 and SAND86-1996, "Accident Sequence Evaluation Program Human Reliability Analysis Procedure," A. D. Swain, Sandia National Laboratories (SNL) (Accident Sequence Evaluation Program), February 1987; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-6] NUREG/CR-4639 and EGG-2458, Vols. 1–5, "Nuclear Computerized Library for Assessing Reactor Reliability (NUCLARR)," B. G. Gilbert, Idaho National Engineering Laboratory (INEL), 1994; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-7] NUREG/CR-5497 and INEEL/EXT-97-01328, "Common-Cause Failure Parameter Estimations," F. Marshall, A. Mosleh, and D. Rasmuson, Idaho National Engineering and Environmental Laboratory (INEEL), 1998; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-8] NUREG/CR-6268 and INEEL/EXT-97-00696, Vols. 1–4 "Common Cause Failure Database and Analysis System," F. Marshall, A. Mosleh, and D. Rasmuson, Idaho National Engineering and Environmental Laboratory (INEEL), 1998; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-9] NUREG/CR-5496 and INEEL/EXT-97-00887, "Evaluation of Loss of Offsite Power Events at Nuclear Power Plants: 1980–1986," C. L. Atwood et al., Idaho National Engineering and Environmental Laboratory (INEEL), 1998; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-10] NUREG/CR-5032 and SAND87-2428, "Modeling Time to Recover and Initiate Event Frequency for Loss-of-Offsite Power Incidents at Nuclear Power Plants," R. L. Iman and S. C. Hora, Sandia National Laboratory (SNL), March 1988; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-11] G. Apostolakis and S. Kaplan, "Pitfalls in Risk Calculations," *Reliability Engineering*, Vol. 2, 135–145, 1981; Elsevier Applied Science, Essex, England

[2-A-12] NUREG/CR-2728 and SAND82-1100, "Interim Reliability Evaluation Program Procedures Guide," D. D. Carlson, Sandia National Laboratories (SNL), March 3, 1983; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-13] "Nuclear Power Plant Response to Severe Accident," IDCOR Technical Summary Report, Atomic Industrial Forum, November 1984; Atomic Industrial Forum, c/o Nuclear Energy Institute (NEI), 1201 F Street NW, Suite 1100, Washington, DC 20004

[2-A-14] NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," December 1990; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-15] NUREG/CR-6595 and BNL-NUREG-52539, "Approach for Estimating the Frequencies of Various Containment Failure Modes and Bypass Events," W. T. Pratt et al., Brookhaven National Laboratory (BNL), January 1999; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-16] NUREG/CR-6928 and INL/EXT-06-11119, "Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants," S. A. Eide et al., Idaho National Laboratory (INL), February 2007; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-17] NUREG-1715, "Component Performance Study, 1987–1998," Vols. 1–4, 2000-2001; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-18] NUREG-0700, Rev. 2, "Human-System Interface Design Review Guidelines," May 2002; U.S.

Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-19] NUREG-1935, “State-of-the-Art Reactor Consequence Analyses (SOARCA) Report,” November 2012; U. S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-20] EPRI 1021081, “Establishing Minimum Acceptable Values for Probabilities of Human Failure Events—Practical Guidance for Probabilistic Risk Assessment,” Interim Report, October 2010; Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[2-A-21] NUREG-1792, “Good Practices for Implementing Human Reliability Analysis (HRA),” April 2005; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-22] NUREG-1855, Rev. 1, “Good Practices for Implementing Human Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decision Making,” July 2016; U. S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-23] EPRI Report TR-101711-T2, “SHARP1—Revised Systematic Human Action Reliability Procedure,” D. T. Wakefield, G. W. Parry, G. W. Hannaman, A. J. Spurgin, March 1993; Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[2-A-24] Regulatory Guide 1.174, Rev. 3, “An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis,” January 2018; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[2-A-25] EPRI 3002003150, “A Process for HRA Dependency Analysis and Considerations on Use of Minimum Values for Joint Human Error Probabilities,” August 2016; Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

PART 3
REQUIREMENTS FOR INTERNAL FLOOD AT-POWER PRA

Section 3-1
Overview of Internal Flood At-Power PRA Requirements

3-1.1 PRA SCOPE

This Part states the technical requirements for a Level 1 and large early release frequency (LERF) analysis of the internal flood hazard group (including water, steam, and oil) while at-power.

3-1.2 COORDINATION WITH OTHER PARTS OF THIS STANDARD

This Part is intended to be used together with Part 1 and Part 2 of this Standard. An internal-events at-power PRA developed in accordance with Part 2 is the starting point for the development of the internal flood PRA model. The internal flood PRA may produce or be accompanied by other hazards, such as seismic-induced flood, and so this Part also coordinates with Part 5, Part 7, Part 8, and Part 9.

(The text presented in **blue font** in this Standard comprise hyperlinks to enable efficient access to referenced sections and elements, requirements, notes, references, etc.)

Section 3-2
Internal Flood PRA Technical Elements and Requirements

The requirements of this Part are organized into the following seven technical elements:
(a) Internal Flood Plant Partitioning (IFPP)
(b) Internal Flood Source Identification and Characterization (IFSO)
(c) Internal Flood Scenario Development (IFSN)
(d) Internal Flood Initiating Event Analysis (IFEV)
(e) Internal Flood PRA Plant Response Analysis (IFPR)
(f) Internal Flood Human Reliability Analysis (IFHR)
(g) Internal Flood Risk Quantification (IFQU)

3-2.1 INTERNAL FLOOD PLANT PARTITIONING (IFPP)

3-2.1.1 Objectives

The objective of Internal Flood Plant Partitioning is to identify plant areas where internal floods can be initiated in such a way that
(a) plant-specific physical layouts and separations are included
(b) flood areas are defined to provide the basis for the identification of flood scenarios and flood-induced accident sequences
(c) the Internal Flood Plant Partitioning is documented to provide traceability of the analysis

Table 3-2.1-1 High Level Requirements for Internal Flood Plant Partitioning (IFPP)

Designator	Requirement
HLR-IFPP-A	The internal flood PRA shall define the physical boundaries of the analysis to include all plant locations relevant to the internal flood PRA.
HLR-IFPP-B	The internal flood PRA shall perform a plant partitioning analysis to identify and define the flood areas to be evaluated in the internal flood PRA.
HLR-IFPP-C	Documentation of Internal Flood Plant Partitioning shall provide traceability of the analysis.

Table 3-2.1-2 Supporting Requirements for HLR-IFPP-A

The internal flood PRA shall define the physical boundaries of the analysis to include all plant locations relevant to the internal flood PRA (HLR-IFPP-A).

Index No. IFPP-A	Capability Category I	Capability Category II
IFPP-A1	INCLUDE within the plant analysis boundary all areas or locations within the licensee-controlled area where an internal flood could adversely affect any equipment to be included in the Internal Flood PRA Plant Response Analysis, including those locations of an adjacent unit that contain shared equipment included in the internal flood PRA.	

Table 3-2.1-3 Supporting Requirements for HLR-IFPP-B

The internal flood PRA shall perform a plant partitioning analysis to identify and define the flood areas to be evaluated in the internal flood PRA (HLR-IFPP-B).

Index No. IFPP-B	Capability Category I	Capability Category II
IFPP-B1	DEFINE flood areas by dividing the plant into physically separate areas where a flood area is viewed as a portion of a building or plant that is separated from other areas by barriers that delay, restrict, or prevent the propagation of floods to adjacent areas.	
IFPP-B2	USE plant-information sources that represent the as-built, as-operated plant to support development of flood areas.	
IFPP-B3	ENSURE that *(a)* collectively, the defined flood areas encompass all locations within the plant analysis boundary, including shared areas and the applicable areas from the adjacent unit for multi-unit sites (see Supporting Requirement (SR) IFPP-A1) *(b)* defined flood areas do not overlap	
IFPP-B4	COLLECT the following information from plant-information sources or via plant walkdown(s): *(a)* spatial information needed for the development of flood areas *(b)* plant design features credited in defining flood areas CONFIRM the accuracy of information collected by conducting walkdown(s)	
IFPP-B5	IDENTIFY the sources of model uncertainty, the related assumptions, and reasonable alternatives associated with the Internal Flood Plant Partitioning in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 3-2.1-4 Supporting Requirements for HLR-IFPP-C

Documentation of the Internal Flood Plant Partitioning shall provide traceability of the analysis (HLR-IFPP-C).

Index No. IFPP-C	Capability Category I	Capability Category II
IFPP-C1	DOCUMENT the process used in the Internal Flood Plant Partitioning analysis, specifying what is used as input, the applied method, and the results. The documentation includes, as a minimum, *(a)* flood areas defined in the analysis and the reasons for excluding any areas within the licensee-controlled area from further analysis *(b)* the general nature and key or unique features of the partitioning elements that define each flood area *(c)* any walkdowns performed in support of the plant partitioning	
IFPP-C2	DOCUMENT the sources of model uncertainty, the related assumptions, and reasonable alternatives (as identified via SR IFPP-B5) associated with the Internal Flood Plant Partitioning.	

3-2.2 INTERNAL FLOOD SOURCE IDENTIFICATION AND CHARACTERIZATION (IFSO)

3-2.2.1 Objectives

The objectives of Internal Flood Source Identification and Characterization are to identify, characterize, and document the plant-specific sources in such a way that

(a) potential flood sources, including water, steam, and other liquids (e.g., lubricating oil), are identified
(b) flood sources for each flood area are identified
(c) flood areas with potential flood sources are retained as the flood-initiating areas
(d) mechanisms that cause the flooding are identified
(e) flood source release characteristics are included
(f) the Internal Flood Source Identification and Characterization is documented to provide traceability of the analysis

Table 3-2.2-1 High Level Requirements for Internal Flood Source Identification and Characterization (IFSO)

Designator	Requirement
HLR-IFSO-A	The potential flood sources in the flood areas and their associated failure mechanisms shall be identified and characterized in a manner sufficient to define flood scenarios.
HLR-IFSO-B	Documentation of the Internal Flood Source Identification and Characterization shall provide traceability of the analysis.

Table 3-2.2-2 Supporting Requirements for HLR-IFSO-A

The potential flood sources in the flood areas and their associated failure mechanisms shall be identified and characterized in a manner sufficient to define flood scenarios (HLR-IFSO-A).

Index No. IFSO-A	Capability Category I	Capability Category II
IFSO-A1	For each flood area, IDENTIFY the potential flood sources, including *(a)* equipment (e.g., piping, valves, pumps) located in the area that is connected to fluid systems *(b)* plant internal flood sources (e.g., tanks or pools) located in the flood area *(c)* plant external flood sources (e.g., reservoirs or rivers) that are connected through some system or structure within the plant boundary	
IFSO-A2	IDENTIFY the potential flood sources that include water, steam, and other liquids (e.g., lubricating oil, fuel oil).	
IFSO-A3	For multi-unit sites with shared systems or structures, INCLUDE any sources with potential multi-unit or cross-unit impacts.	
IFSO-A4	RETAIN flood areas for further consideration as flood-initiating areas unless it can be concluded, using criteria SCR-3 from Table 1-1.8-1, that they do not contain any of the potential flood sources identified via SR IFSO-A1, SR IFSO-A2, and SR IFSO-A3.	
IFSO-A5	For each potential flood source, IDENTIFY the failure mechanisms that would result in a release of water, steam, or other liquids from the flood source, including *(a)* failure modes of components such as pipes, tanks, gaskets, expansion joints, fittings, and seals *(b)* human-induced mechanisms that could lead to overfilling tanks or the diversion of flow through openings created to perform maintenance *(c)* inadvertent actuation of a fire suppression system *(d)* other events resulting in a release into the flood area	
IFSO-A6	For each source and its identified failure mechanism, IDENTIFY the characteristic of release and the capacity of the source, including *(a)* a characterization of the breach (e.g., leak, rupture, spray) *(b)* applicable range of flow rates *(c)* capacity of source (e.g., gallons of water) *(d)* the pressure and temperature of the source	
IFSO-A7	IDENTIFY the location of flood sources and the possibility of flooding of the area due to inleakage pathways from plant-information sources or via plant walkdown(s). CONFIRM the accuracy of information collected by conducting plant walkdown(s).	
IFSO-A8	IDENTIFY the sources of model uncertainty, the related assumptions, and reasonable alternatives associated with the Internal Flood Source Identification and Characterization in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 3-2.2-3 Supporting Requirements for HLR-IFSO-B

Documentation of the Internal Flood Source Identification and Characterization shall provide traceability of the analysis (HLR-IFSO-B).

Index No. IFSO-B	Capability Category I	Capability Category II
IFSO-B1	DOCUMENT the process used in the Internal Flood Source Identification and Characterization specifying what is used as input, the applied method, and the results. The documentation includes, as a minimum, *(a)* identified flood sources and the resulting list of sources to be further examined *(b)* Identified failure mechanisms and flood characteristics *(c)* basis for any screening performed *(d)* any calculations or other analyses used to support or refine the flooding evaluation *(e)* any walkdowns performed.	
IFSO-B2	DOCUMENT the sources of model uncertainty, the related assumptions, and reasonable alternatives (as identified via SR IFSO-A8) associated with the Internal Flood Source Identification and Characterization.	

3-2.3 INTERNAL FLOOD SCENARIO DEVELOPMENT (IFSN)

3-2.3.1 Objectives

The objectives of Internal Flood Scenario Development are to define, screen, and document the plant-specific internal flood scenarios that could lead to core damage in such a way that

(a) systematic identification of flood scenarios is performed

(b) identified flood areas and flood sources are included

(c) flood source release characteristics are included

(d) flood barriers are included

(e) flood propagation paths are identified and included

(f) automatic and/or operator (manual) responses to terminate a flood and mitigate its consequences are included

(g) impact of flood on plant performance and damage to plant equipment are included

(h) the Internal Flood Scenario Development is documented to provide traceability of the analysis

Table 3-2.3-1 High Level Requirements for Internal Flood Scenario Development (IFSN)

Designator	Requirement
HLR-IFSN-A	Flood scenarios shall be developed and characterized for each flood source in each retained flood area by identifying the propagation path(s) of the source and the affected SSCs.
HLR-IFSN-B	Documentation of the Internal Flood Scenario Development shall provide traceability of the analysis.

Table 3-2.3-2 Supporting Requirements for HLR-IFSN-A

Flood scenarios shall be developed and characterized for each flood source in each retained flood area by identifying the propagation path(s) of the source and the affected SSCs (HLR-IFSN-A).

Index No. IFSN-A	Capability Category I	Capability Category II
IFSN-A1	IDENTIFY the flood propagation path from the flood source to its area(s) of accumulation for each flood source in each flood area retained in the internal flood PRA.	
IFSN-A2	IDENTIFY plant design features that support the ability to terminate or contain the flood propagation for each flood source in each flood area retained in the internal flood PRA. INCLUDE the presence of *(a)* flood alarms *(b)* flood dikes, curbs, sumps, water-tight doors, and all other flood barriers *(c)* drains (i.e., physical structures that can function as drains) *(d)* sump pumps *(e)* spray shields *(f)* blowout panels or dampers with automatic or manual operation capability	
IFSN-A3	IDENTIFY those automatic actuations or operator responses that have the ability to terminate or contain the flood propagation for each flood source in each flood area retained in the internal flood PRA.	
IFSN-A4	ESTIMATE the capacity of the drains and the amount of water retained by sumps, berms, dikes, and curbs. INCLUDE these factors in estimating flood volumes and evaluating structure, system, and component (SSC) impacts from flooding.	
IFSN-A5	IDENTIFY the following SSCs located in flood area retained in the internal flood PRA, the spatial location of each identified SSC in the area, and any credited flooding mitigative features for each identified SSC that *(a)* are required to respond to an internal flood-induced initiating event or whose failure would challenge normal plant operation and are susceptible to flood *(b)* impact the ability to terminate, delay, or contain the flood propagation	
IFSN-A6	For the SSCs identified in SR IFSN-A5, IDENTIFY the susceptibility of each SSC in a flood area to submergence and spray failure mechanisms. Either ASSESS, qualitatively, the impact of the flood-induced mechanisms that are not explicitly addressed (e.g., jet impingement, pipe whip) or specify that these mechanisms are not included in the scope of the evaluation.	For the SSCs identified in SR IFSN-A5, IDENTIFY *(a)* the susceptibility of each SSC in a flood area to submergence, spray, humidity, and condensation failure mechanisms *(b)* the susceptibility of each SSC to submergence, spray, jet impingement, pipe whip, temperature, pressure, humidity, and condensation failure mechanisms for flood scenarios involving a high energy line break JUSTIFY any determination that SSCs as identified in SR IFSN-A5 within the flood area are not susceptible to flood-induced failure mechanisms.
IFSN-A7	When determining susceptibility of SSCs to flood-induced failure mechanisms (see SR IFSN-A6), INCLUDE the SSCs identified in SR IFSN-A5 unless the SSC functionality in the presence of internal flood effects can be supported by one or a combination of the following: *(a)* test or operational data *(b)* engineering analysis *(c)* expert judgment (satisfy the requirements of Section 1-4.2, Use of Expert Judgment)	

Table 3-2.3-2 Supporting Requirements for HLR-IFSN-A (Cont'd)

Flood scenarios shall be developed and characterized for each flood source in each retained flood area by identifying the propagation path(s) of the source and the affected SSCs (HLR-IFSN-A).

Index No. IFSN-A	Capability Category I	Capability Category II
IFSN-A8	IDENTIFY interarea propagation between areas connected via permanent opening(s), drain line in the normal flow path, and open doors, stairwells, and hatchways.	IDENTIFY interarea propagation between areas connected via *(a)* drain lines in the normal flow path *(b)* backflow through drain lines involving failed check valves *(c)* pipe and cable penetrations (including cable trays) without penetration seals robust enough to prevent propagation *(d)* doors and gaps below doors *(e)* stairwells *(f)* hatchways *(g)* blowout panels *(h)* HVAC ducts *(i)* floor grates and plugs *(j)* penetration seals INCLUDE potential for structural failure (e.g., doors, walls, penetration seals) due to flooding loads.
IFSN-A9	For each flood scenario, using conservative plant-specific values for flood-area design features, ESTIMATE the following except where the requirements are not applicable: *(a)* conservative (i.e., bounding) flood source inventory, break size, and release rate *(b)* conservative flood propagation and drainage rates *(c)* conservative volume fractions occupied by SSCs for the affected flood areas (for flood-submergence scenarios only) *(d)* conservative potential of flood barrier failures *(e)* conservative humidity and temperature conditions for the affected flood areas (for steam release scenario only)	For each flood scenario that is risk significant, using plant-specific values for flood-area design features, CALCULATE the following except where the requirements are not applicable: *(a)* flood source inventory, break size, and release rate *(b)* flood propagation and drainage rates by including flow pathways through floor drains, floor grates, floor hatches, gaps below doorways, wall openings, and HVAC ducts *(c)* SSC occupancy fractions for the affected flood areas (for flood-submergence scenarios only) *(d)* potential of flood barrier failures *(e)* humidity and temperature conditions for the affected flood areas (for steam release scenarios only)
IFSN-A10	For each flood scenario that causes submergence, ESTIMATE the conservative flood heights and the associated times to damage SSCs that are included in the internal flood PRA model and are located in the flood-initiating area and areas in potential propagation paths. ASSESS the impact on SSCs included in the internal flood PRA model caused by submergence, spray, harsh environment, or hydraulic loading in the flood-initiating area and areas in potential propagation paths.	For each flood scenario that causes submergence and is risk significant, CALCULATE the flood heights and the associated times to damage SSCs that are included in the internal flood PRA model and are located in the flood-initiating area and areas in potential propagation paths. ASSESS the impact on SSCs included in the internal flood PRA model caused by submergence, spray, harsh environment, or hydraulic loading in the flood-initiating area and areas in potential propagation paths.
IFSN-A11	In the calculation of flood height in each flood area for each flood scenario that causes submergence, ENSURE that the propagation flow rates used do not result in nonconservative flood height for either the originating flood area (outleakage flow rate) or the receiving flood area (inleakage flow rate) along the propagation path.	
IFSN-A12	ENSURE that an appropriate duration is used in the flood height analysis for each flood scenario that causes submergence so that the maximum flood height or critical flood height for susceptible equipment in each flood area along the flood propagation path (including the flood-initiating area) is reached.	

Table 3-2.3-2 Supporting Requirements for HLR-IFSN-A (Cont'd)

Flood scenarios shall be developed and characterized for each flood source in each retained flood area by identifying the propagation path(s) of the source and the affected SSCs (HLR-IFSN-A).

Index No. IFSN-A	Capability Category I	Capability Category II
IFSN-A13	DEVELOP flood scenarios by examining the equipment and relevant plant features in the flood-initiating area and areas in potential propagation paths, giving credit for flood mitigation systems or operator actions identified in SR IFSN-A3 and identifying susceptible SSCs. INCLUDE in the development of scenarios, the flood area, flood source, flood rate, flood propagation path, possibility of flood barrier failure, flood impact on plant SSCs, and human actions considered in flood initiation, mitigation, and termination.	
IFSN-A14	For multi-unit sites with shared systems or structures, INCLUDE multi-unit flood scenarios.	
IFSN-A15	RETAIN flood areas unless it can be concluded, using criteria SCR-3 from Table 1-1.8-1, that flooding of the flood area does not cause a flood-induced initiating event or a need for immediate plant shutdown, *and* any of the following applies: *(a)* The flood area (including adjacent areas where flood sources can propagate) contains no equipment modeled in the PRA or contains no equipment that supports the function of the modeled equipment. *(b)* The flood area has no flood sources sufficient to cause failure (e.g., through spray, immersion, or other applicable cause) of the equipment identified in SR IFSN-A5 (including equipment in adjacent areas where floods may propagate). *(c)* SR IFSN-A16 is met for all flood sources within that flood area. ENSURE that failure of a barrier resulting in interarea propagation is not used to justify screening out of flood areas (i.e., do not credit such failures as a means of beneficially draining the area without justification).	
IFSN-A16	For flood areas retained via SR IFSN-A15, RETAIN flood sources unless it is concluded, using criteria SCR-3 from Table 1-1.8-1, that flooding of the flood area, based on the limiting flood defined for that source, does not cause an initiating event nor a need for immediate plant shutdown due to loss of function of one or more SSCs caused by the flood, *and* each of the following applies: *(a)* The flood area contains flood mitigation systems capable of preventing unacceptable flood levels. *(b)* The nature of the limiting flood does not cause failure of the flood mitigation systems or SSCs that are needed to prevent core damage or large early release due to a flood-induced failure mechanism. *(c)* There is no propagation to another flood area. ENSURE that mitigation systems are not used for screening out flood sources unless there is a basis for crediting the capability and reliability of the flood mitigation system(s).	
IFSN-A17	COLLECT the following information from plant-information sources or via plant walkdown(s): *(a)* SSCs located within each defined flood area *(b)* flood, spray, or other applicable mitigative features of the SSCs located within each defined flood area *(c)* flood propagation paths CONFIRM the accuracy of information collected by conducting walkdown(s).	
IFSN-A18	IDENTIFY the sources of model uncertainty, the related assumptions, and reasonable alternatives associated with the Internal Flood Scenario Development in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 3-2.3-3 Supporting Requirements for HLR-IFSN-B

Documentation of the Internal Flood Scenario Development shall provide traceability of the analysis (HLR-IFSN-B).

Index No. IFSN-B	Capability Category I	Capability Category II
IFSN-B1	DOCUMENT the process used in the Internal Flood Scenario Development specifying what is used as input, the applied method, and the results. The documentation includes, as minimum, *(a)* flood propagation paths and associated supporting calculations *(b)* accident-mitigating features and barriers credited in the analysis and associated justification *(c)* the flooding scenarios included in the analysis and any process used to screen out any of them *(d)* basis of any screening performed *(e)* justifications and calculations used in the determination of flood-induced failure mechanisms (e.g., justification for the nonsusceptibility of SSCs to flood-induced failure mechanisms for modeled flood scenarios) *(f)* any calculations or other analyses used to support or refine the flooding evaluation *(g)* any walkdowns performed	
IFSN-B2	DOCUMENT the sources of model uncertainty, the related assumptions, and reasonable alternatives (as identified via SR IFSN-A18) associated with the Internal Flood Scenario Development.	

3-2.4 INTERNAL FLOOD INITIATING EVENT ANALYSIS (IFEV)

3-2.4.1 Objectives

The objectives of Internal Flood Initiating Event Analysis are to identify, quantify, and document the applicable flood-induced initiating event for each flood scenario that could lead to core damage in such a way that

(a) internal flood-induced initiating events that challenge normal plant operation and that require successful mitigation to prevent core damage are included

(b) internal flood-induced initiating events are grouped according to mitigation requirements to facilitate the efficient modeling of plant response

(c) the frequencies of initiating event groups are quantified

(d) the Internal Flood Initiating Event Analysis is documented to provide traceability of the analysis

Table 3-2.4-1 High Level Requirements for Internal Flood Initiating Event Analysis (IFEV)

Designator	Requirement
HLR-IFEV-A	The Internal Flood Initiating Event Analysis shall identify flood-induced initiating events to be evaluated in the Internal Flood PRA Plant Response Analysis.
HLR-IFEV-B	The Internal Flood Initiating Event Analysis shall quantify the annual frequencies of scenarios resulting in flood-induced initiating events.
HLR-IFEV-C	Documentation of the Internal Flood Initiating Event Analysis shall provide traceability of the analysis.

Table 3-2.4-2 Requirements for HLR-IFEV-A

The Internal Flood Initiating Event Analysis shall identify flood-induced initiating events to be evaluated in the Internal Flood PRA Plant Response Analysis (HLR-IFEV-A).

Index No. IFEV-A	Capability Category I	Capability Category II
IFEV-A1	GROUP flood scenarios identified in SR IFSN-A13 only when flood scenarios *(a)* can be considered similar in terms of plant response, success criteria, timing, and the effect on the operability and performance of operators and relevant mitigating systems, or *(b)* can be bounded by the worst-case impacts within the group.	GROUP flood scenarios identified in SR IFSN-A13 only when flood scenarios *(a)* can be considered similar in terms of plant response, success criteria, timing, and the effect on the operability and performance of operators and relevant mitigating systems, or *(b)* can be bounded by the worst-case impacts, including radionuclide release potential, within the group and the grouping does not impact risk-significant accident sequences.
IFEV-A2	For each flood scenario or flood-scenario group defined according to SR IFEV-A1, IDENTIFY the corresponding initiating-event group from the internal-events PRA. If an appropriate initiating event or initiating-event group does not exist, CREATE a new initiating-event group and meet the Capability Category I (CC-I) SR IE-A3, SR IE-A7, SR IE-A8, and SR IE-A9 in Part 2 for Initiating Event Analysis.	For each flood scenario or flood-scenario group defined according to SR IFEV-A1, IDENTIFY the corresponding initiating-event group from the internal-events PRA. If an appropriate initiating event or initiating-event group does not exist, CREATE a new initiating-event group, and meet the Capability Category II (CC-II) SR IE-A3, SR IE-A7, SR IE-A8, and SR IE-A9 in Part 2 for Initiating Event Analysis.
IFEV-A3	For multi-unit sites with shared systems or structures, INCLUDE multi-unit impacts on SSCs in the definition and grouping of flood-induced initiating events.	

Table 3-2.4-3 Requirements for HLR-IFEV-B

The Internal Flood Initiating Event Analysis shall quantify the annual frequencies of scenarios resulting in flood-induced initiating events (HLR-IFEV-B).

Index No. IFEV-B	Capability Category I	Capability Category II
IFEV-B1	If choosing to include in the flood scenario definition mitigating features that have the ability to terminate or contain the flood propagation, QUANTIFY their probabilities of failure and SATISFY the CC-I requirements in HLR-SY-A and HLR-SY-B for Systems Analysis, as well as HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D for Data Analysis in Part 2 except where the requirements are not applicable.	If choosing to include in the flood scenario definition mitigating features that have the ability to terminate or contain the flood propagation, QUANTIFY their probabilities of failure and SATISFY the CC-II requirements in HLR-SY-A and HLR-SY-B for Systems Analysis, as well as HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D for Data Analysis in Part 2 except where the requirements are not applicable.
IFEV-B2	QUANTIFY the frequency for each flood-induced initiating event or initiating-event group on a reactor-year basis, INCLUDE the probability of failure of any mitigating features (e.g., SR IFEV-B1) and/or human error probabilities (HEPs) (e.g., SR IFHR-C1) that have been used to define the flood scenario and the associated flood-induced initiating event, and satisfy the CC-I requirements in HLR-IE-C in Part 2 for Initiating Event Analysis except where the requirements are not applicable.	QUANTIFY the frequency for each flood-induced initiating event or initiating-event group on a reactor-year basis, INCLUDE the probability of failure of any mitigating features (e.g., SR IFEV-B1) and/or HEPs (e.g., SR IFHR-C1) that have been used to define the flood scenario and the associated flood-induced initiating event, and satisfy the CC-II requirements in HLR-IE-C in Part 2 for Initiating Event Analysis except where the requirements are not applicable.
IFEV-B3	In estimating the flood initiating-event frequencies, USE one or a combination of the following: *(a)* generic operating experience *(b)* pipe, component, and tank rupture failure rates from generic data sources *(c)* expert judgment (satisfy the requirements of Section 1-4.2, Use of Expert Judgment)	COLLECT plant-specific information on plant design, operating practices, and conditions that may impact flood initiating-event frequency (e.g., material condition of fluid systems, experience with water hammer, and maintenance-induced floods). INCLUDE pipe age-dependent failure rates where appropriate and when supported by applicable generic or plant-specific data. In estimating the flood-induced initiating-event frequencies, USE the above-collected plant-specific information and one or a combination of the following: *(a)* generic and plant-specific operating experience *(b)* pipe, component, and tank rupture failure rates from generic data sources and plant-specific experience *(c)* expert judgment (satisfy the requirements of Section 1-4.2, Use of Expert Judgment) for consideration of the plant-specific information collected

Table 3-2.4-3 Requirements for HLR-IFEV-B (Cont'd)

The Internal Flood Initiating Event Analysis shall quantify the annual frequencies of scenarios resulting in flood-induced initiating events (HLR-IFEV-B).

Index No. IFEV-B	Capability Category I	Capability Category II
IFEV-B4	ESTIMATE the frequency of human-induced floods during maintenance through application of one of the following options: *(a)* available generic data *(b)* available plant-specific data *(c)* use of expert judgment (satisfy the requirements of Section 1-4.2, Use of Expert Judgment), or *(d)* evaluation of human failure events (HFEs) during maintenance activities that can lead to human-induced floods and meet the CC-I requirements for HLR-HR-A, HLR-HR-B, HLR-HR-C, and HLR-HR-D in Part 2 except where the requirements are not applicable.	ESTIMATE the frequency of human-induced floods during maintenance through application of available generic and plant-specific data, or by using human reliability techniques in evaluating plant-specific maintenance activities. EVALUATE the HFEs during maintenance activities that can lead to human-induced floods and meet the CC-II requirements for HLR-HR-A, HLR-HR-B, HLR-HR-C, and HLR-HR-D in Part 2 except where the requirements are not applicable.
IFEV-B5	RETAIN flood-induced initiating events or initiating-event groups unless it can be concluded that the requirements in SR IE-C6 in Part 2 can be satisfied or any of the following items are satisfied: *(a)* SCR-2 from Table 1-1.8-1, as applied to the flood initiating-event groups, is directly met, or *(b)* the flood-induced initiating event affects only components in a single system, and it can be shown that the product of the frequency of the flood-induced initiating event and the probability of SSC failure given the flood is two orders of magnitude lower than the product of the nonflooding frequency for the corresponding initiating event in the PRA and the random (non-flood-induced) failure probability of the same SSCs that are assumed failed by the flood.	
IFEV-B6	IDENTIFY the sources of model uncertainty, the related assumptions, and reasonable alternatives associated with the Internal Flood Initiating Event Analysis in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 3-2.4-4 Supporting Requirements for HLR-IFEV-C

Documentation of the Internal Flood Initiating Event Analysis shall provide traceability of the analysis (HLR-IFEV-C).

Index No. IFEV-C	Capability Category I	Capability Category II
IFEV-C1	DOCUMENT the process used in the Internal Flood Initiating Event Analysis specifying what is used as input, the applied method, and the results. The documentation includes, as a minimum, *(a)* basis for grouping and subsuming flood-induced initiating events *(b)* derivation of flood-induced initiating-event frequencies *(c)* component unreliabilities/unavailabilities and HEPs used in the analysis (i.e., the data values unique to the internal flood analysis) *(d)* any calculations or other analyses used to support or refine the flooding evaluation *(e)* process and basis for screening out flood-induced initiating events *(f)* meeting the documentation requirements in SR DA-E1 for Data Analysis, SR SY-C1 for Systems Analysis, and SR IE-D1 for Initiating Event Analysis in Part 2 except where the requirements are not applicable	
IFEV-C2	DOCUMENT the sources of model uncertainty, the related assumptions, and reasonable alternatives (as identified via SR IFEV-B6) associated with the Internal Flood Initiating Event Analysis.	

3-2.5 INTERNAL FLOOD PRA PLANT RESPONSE ANALYSIS (IFPR)

The objectives of the Internal Flood PRA Plant Response Analysis are to develop the internal flood-induced accident sequences and the associated system, data, and human reliability analyses in a way such that

(a) all of the internal flood-induced initiating events identified are included

(b) risk-significant accident sequences for each internal flood-induced initiating event are included

(c) risk-significant contributors including operator actions, mitigation systems, and phenomena that can alter internal flood accident sequences are included in the accident sequence model

(d) plant-specific dependencies are represented in the accident sequences

(e) end states are clearly defined to be core damage or successful mitigation with capability to support the Level 1 to Level 2 interface

(f) the internal flood PRA plant response analysis model provides the basis for the quantification of the accident sequences that may result from the internal flood scenarios and for the identification of the accident sequence cutsets and risk-significant contributors

(g) document the Internal Flood PRA Plant Response Analysis to provide traceability of the analysis

The Internal Flood PRA Plant Response Analysis requirements are written in anticipation that analysts will not be performing this technical element in a vacuum but will instead start with an internal-events PRA plant response model that has been assessed against Part 2 of this Standard. Many of the requirements in Part 3 call upon parallel requirements found in Part 2 with clarifications as noted herein to produce the Internal Flood PRA Plant Response Analysis.

The Internal Flood PRA Plant Response Analysis includes modeling of the equipment failure modes attributable to internal flood-induced damage to plant components depending on the nature of the flooding scenario.

It is expected that the Internal Flood PRA Plant Response Analysis model will be constructed by modifying the corresponding internal-events PRA models, and the Internal Flood PRA Plant Response Analysis requirements are written from this perspective. Elements of the Internal Flood PRA Plant Response Analysis that are carried over directly from the internal-events PRA are assumed to meet the same Capability Category as assigned for the internal-events PRA, unless it requires modification or reanalysis given the specific context of an internal flood event. In such cases, the assessment of the Capability Category met by the internal flood portion of the PRA may be unique.

Table 3-2.5-1 High Level Requirement for Internal Flood PRA Plant Response Analysis (IFPR)

Designator	Requirement
HLR-IFPR-A	The internal flood PRA shall include the Internal Flood PRA Plant Response Analysis capable of supporting HLR-IFQU-A, HLR-IFQU-B, HLR-IFQU-C, HLR-IFQU-D, HLR-IFQU-E, and HLR-IFQU-F.
HLR-IFPR-B	The Internal Flood PRA Plant Response Analysis shall include flood-induced initiating events, both flood-induced and random failures of equipment, flood-specific as well as non-flood-related human failures associated with safe shutdown, accident progression events (e.g., containment failure modes), and the supporting probability data (including uncertainty) based on the SRs stated under this High Level Requirement (HLR) that parallel, as appropriate, Part 2 of this Standard, for internal-events PRA.
HLR-IFPR-C	Documentation of the Internal Flood PRA Plant Response Analysis shall provide traceability of the analysis.

Table 3-2.5-2 Supporting Requirements for HLR-IFPR-A

The internal flood PRA shall include the Internal Flood PRA Plant Response Analysis capable of supporting HLR-IFQU-A, HLR-IFQU-B, HLR-IFQU-C, HLR-IFQU-D, HLR-IFQU-E, and HLR-IFQU-F (HLR-IFPR-A).

Index No. IFPR-A	Capability Category I	Capability Category II
IFPR-A1	CONSTRUCT the internal flood PRA plant response model so that it is capable of determining flood-induced conditional core damage probabilities (CCDPs) and conditional large early release probabilities (CLERPs) for the internal flood scenarios and their associated flood-induced impacts on mitigating equipment and operator actions.	
IFPR-A2	CONSTRUCT the internal flood PRA plant response model so that it is capable of determining flood-induced core damage frequencies (CDFs) and flood-induced LERFs by applying the flood initiating-event frequencies (see HLR-IFEV-A and HLR-IFEV-B) to the quantification.	
IFPR-A3	CONSTRUCT the internal flood PRA plant response model so that it is capable of determining the risk-significant contributors to the flood-induced risk consistent with the Internal Flood Risk Quantification (see Section 3-2.7).	

Table 3-2.5-3 Supporting Requirements for HLR-IFPR-B

The Internal Flood PRA Plant Response Analysis shall include flood-induced initiating events, both flood-induced and random failures of equipment, flood-specific as well as non-flood-related human failures associated with safe shutdown, accident progression events (e.g., containment failure modes), and the supporting probability data (including uncertainty) based on the SRs stated under this HLR that parallel, as appropriate, Part 2 of this Standard, for internal-events PRA (HLR-IFPR-B).

Index No. IFPR-B	Capability Category I	Capability Category II
IFPR-B1	USE the internal-events PRA initiating events and accident sequences for both CDF and LERF as the basis for development of the internal flood PRA plant response model.	
IFPR-B2	ENSURE that significant deficiencies identified during the peer review for the internal-events and other hazard PRAs that are relevant to the results of the internal flood PRA are resolved and incorporated into the development of the internal flood PRA plant response model.	
IFPR-B3	For each flood scenario or flood-scenario group, REVIEW the accident sequences for the associated initiating-event group to confirm applicability of the accident sequence model. If appropriate accident sequences do not exist, MODIFY existing accident sequences or CREATE new sequences as necessary to include any unique accident sequences that could result from the flood scenario and associated flood- induced failure mechanisms or phenomena. For the defined accident sequences, meet the CC-I requirements in HLR-AS-A and HLR-AS-B in Part 2 for Accident Sequence Analysis except where the requirements are not applicable.	For each flood scenario or flood-scenario group, REVIEW the accident sequences for the associated initiating-event group to confirm applicability of the accident sequence model. If appropriate accident sequences do not exist, MODIFY existing accident sequences or CREATE new sequences as necessary to include any unique accident sequences that could result from the flood scenario and associated flood- induced failure mechanisms or phenomena. For the defined accident sequences, meet the CC-II requirements in HLR-AS-A and HLR-AS-B in Part 2 for Accident Sequence Analysis except where the requirements are not applicable.
IFPR-B4	MODEL accident sequences for any new initiating events identified per SR IFEV-A2 that represent possible plant responses to the flood-induced initiating events and meet the requirements in HLR-AS-A and HLR-AS-B for the Accident Sequence Analysis except where the requirements are not applicable with the following clarifications: *(a)* All the SRs under the CC-I requirements of HLR-AS-A and HLR-AS-B in Part 2 are to be addressed in the context of internal flood scenarios *(b)* When applying SR AS-A5 in Part 2 to internal flood PRA, INCLUDE flood response procedures as well as emergency operating procedures and abnormal procedures	MODEL accident sequences for any new initiating events identified per SR IFEV-A2 that represent possible plant responses to the flood-induced initiating events and meet the requirements in HLR-AS-A and HLR-AS-B for the Accident Sequence Analysis except where the requirements are not applicable with the following clarifications: *(a)* All the SRs under the CC-II requirements of HLR-AS-A and HLR-AS-B in Part 2 are to be addressed in the context of internal flood scenarios *(b)* When applying SR AS-A5 in Part 2 to internal flood PRA, INCLUDE flood response procedures as well as emergency operating procedures and abnormal procedures
IFPR-B5	IDENTIFY any cases where new or modified success criteria will be needed to support the internal flood PRA and SATISFY the CC-I requirements in HLR-SC-A in Part 2 for Success Criteria except where the requirements are not applicable.	IDENTIFY any cases where new or modified success criteria will be needed to support the internal flood PRA and SATISFY the CC-II requirements in HLR-SC-A in Part 2 for Success Criteria except where the requirements are not applicable.

Table 3-2.5-3 Supporting Requirements for HLR-IFPR-B (Cont'd)

The Internal Flood PRA Plant Response Analysis shall include flood-induced initiating events, both flood-induced and random failures of equipment, flood-specific as well as non-flood-related human failures associated with safe shutdown, accident progression events (e.g., containment failure modes), and the supporting probability data (including uncertainty) based on the SRs stated under this HLR that parallel, as appropriate, Part 2 of this Standard, for internal-events PRA (HLR-IFPR-B).

Index No. IFPR-B	Capability Category I	Capability Category II
IFPR-B6	DEFINE any new or modified success criteria identified per SR IFPR-B5, and MODEL the internal flood PRA plant response by using these success criteria that meet the CC-I requirements in HLR-SC-B in Part 2 for Success Criteria except where the requirements are not applicable.	DEFINE any new or modified success criteria identified per SR IFPR-B5, and MODEL the internal flood PRA plant response by using these success criteria that meet the CC-II requirements in HLR-SC-B in Part 2 for Success Criteria except where the requirements are not applicable.
IFPR-B7	MODIFY the existing systems models to include flood-induced failure mechanisms identified in accordance with SR IFSN-A6 or, if needed, PERFORM new systems analysis and meet the CC-I requirements in HLR-SY-A and HLR-SY-B in Part 2 for Systems Analysis within the context of internal flood scenarios except where the requirements are not applicable. INCLUDE in the internal flood PRA plant response model the effects of: *(a)* internal flood-induced equipment failures *(b)* internal flood-specific operator actions as identified per the Internal Flood Human Reliability Analysis	MODIFY the existing systems models to include flood-induced failure mechanisms identified in accordance with SR IFSN-A6 or, if needed, PERFORM new systems analysis and meet the CC-II requirements in HLR-SY-A and HLR-SY-B in Part 2 for Systems Analysis within the context of internal flood scenarios except where the requirements are not applicable. INCLUDE in the internal flood PRA plant response model the effects of: *(a)* internal flood-induced equipment failures *(b)* internal flood-specific operator actions as identified per the Internal Flood Human Reliability Analysis
IFPR-B8	IDENTIFY any new accident progression sequences beyond the onset of core damage that would be applicable to the internal flood PRA that were not addressed for LERF estimation in the internal-events PRA.	
IFPR-B9	MODEL any new accident progression sequences beyond the onset of core damage identified per SR IFPR-B8 to determine the flood-induced LERF, and SATISFY the requirements in HLR-LE-A, HLR-LE-B, HLR-LE-C, and HLR-LE-D for LERF Analysis except where the requirements are not applicable with the following clarifications: *(a)* All the SRs under HLR-LE-A, HLR-LE-B, HLR-LE-C, and HLR-LE-D in Part 2 are to be addressed in the context of internal flood scenarios *(b)* CC-I SRs in SR LE-C2 in Part 2 are to be met in a manner consistent with HLR-IFHR-A, HLR-IFHR-B, HLR-IFHR-C, and HLR-IFHR-D *(c)* CC-I SRs in SR LE-C6 in Part 2 are to be met in a manner consistent with SR IFPR-B7 *(d)* CC-I SRs in SR LE-C8 in Part 2 are to be met in a manner consistent with SR IFPR-B4	MODEL any new accident progression sequences beyond the onset of core damage identified per SR IFPR-B8 to determine the flood-induced LERF, and SATISFY the requirements in HLR-LE-A, HLR-LE-B, HLR-LE-C, and HLR-LE-D for LERF Analysis except where the requirements are not applicable with the following clarifications: *(a)* All the SRs under HLR-LE-A, HLR-LE-B, HLR-LE-C, and HLR-LE-D in Part 2 are to be addressed in the context of internal flood scenarios *(b)* CC-II SRs in SR LE-C2 in Part 2 are to be met in a manner consistent with HLR-IFHR-A, HLR-IFHR-B, HLR-IFHR-C, and HLR-IFHR-D *(c)* CC-II SRs in SR LE-C6 in Part 2 are to be met in a manner consistent with SR IFPR-B7 *(d)* CC-II SRs in SR LE-C8 in Part 2 are to be met in a manner consistent with SR IFPR-B4

Table 3-2.5-3 Supporting Requirements for HLR-IFPR-B (Cont'd)

The Internal Flood PRA Plant Response Analysis shall include flood-induced initiating events, both flood-induced and random failures of equipment, flood-specific as well as non-flood-related human failures associated with safe shutdown, accident progression events (e.g., containment failure modes), and the supporting probability data (including uncertainty) based on the SRs stated under this HLR that parallel, as appropriate, Part 2 of this Standard, for internal-events PRA (HLR-IFPR-B).

Index No. IFPR-B	Capability Category I	Capability Category II
IFPR-B10	REVIEW component mission times used in the internal flood PRA plant response model for the flood scenarios retained to ensure that the impacts of the flood do not invalidate the assumed component mission time due to sustained impacts on the plant response. SATISFY the CC-I SRs in SR SC-A5 in Part 2 for Success Criteria, except where the SRs are not applicable.	REVIEW component mission times used in the internal flood PRA plant response model for the flood scenarios retained to ensure that the impacts of the flood do not invalidate the assumed component mission time due to sustained impacts on the plant response. SATISFY the CC-II SRs in SR SC-A5 in Part 2 for Success Criteria, except where the SRs are not applicable.
IFPR-B11	IDENTIFY the sources of model uncertainty, the related assumptions, and reasonable alternatives associated with the Internal Flood PRA Plant Response Analysis in a manner that supports the applicable SRs of Table 2-2.7-6 (HLR-QU-E).	

Table 3-2.5-4 Supporting Requirements for HLR-IFPR-C

Documentation of the Internal Flood PRA Plant Response Analysis shall provide traceability of the analysis (HLR-IFPR-C).

Index No. IFPR-C	Capability Category I	Capability Category II
IFPR-C1	DOCUMENT the process used in the development of the Internal Flood PRA Plant Response Analysis specifying what is used as input, the applied methods, and the results. The documentation includes, as a minimum, *(a)* description of the internal flood-induced initiating events and how the internal-events PRA model was modified to model the internal flood-induced initiating events *(b)* description of the success criteria established for each internal flood-induced initiating event including the bases for the criteria *(c)* description of the internal flood-induced accident sequence model developed for each internal flood-induced initiating event *(d)* description of the revised and the new system analyses used to support the quantification of the internal flood-induced accident sequence model *(e)* meeting the documentation requirements in HLR-IE-D for the Initiating Event Analysis, HLR-AS-C for the Accident Sequence Analysis, HLR-SC-C for Success Criteria, HLR-SY-C for Systems Analysis, and HLR-DA-E for Data Analysis in Part 2	
IFPR-C2	DOCUMENT the sources of model uncertainty, related assumptions, and reasonable alternatives (as identified via SR IFPR-B11) associated with the Internal Flood PRA Plant Response Analysis.	

3-2.6 INTERNAL FLOOD HUMAN RELIABILITY ANALYSIS (IFHR)

3-2.6.1 Objectives

The objectives of the Internal Flood Human Reliability Analysis are to identify the HFEs, quantify the HEPs for those HFEs to which they apply, and document the human reliability analysis (HRA) in such a way that

(a) existing HFEs (e.g., from the internal-events PRA) are modified to include internal flood-specific performance-shaping factors

(b) flood area-specific and flood scenario-specific human actions are included

(c) internal flood procedures and direct operator actions taken to maintain acceptable plant configurations and to achieve safe shutdown are included

(d) HEPs are quantified

(e) the Internal Flood Human Reliability Analysis is documented to provide traceability of the analysis

Table 3-2.6-1 High Level Requirements for Internal Flood Human Reliability Analysis (IFHR)

Designator	Requirement
HLR-IFHR-A	The internal flood PRA shall identify human actions relevant to the accident sequences in the Internal Flood PRA Plant Response Analysis.
HLR-IFHR-B	The internal flood PRA shall include HFEs in the Internal Flood PRA Plant Response Analysis.
HLR-IFHR-C	The internal flood PRA shall quantify HEPs accounting for the plant-specific and scenario-specific influences on human performance, particularly including the effects of internal floods, and addressing potential dependencies.
HLR-IFHR-D	The internal flood PRA shall include recovery actions only if it has been demonstrated that the actions are plausible and feasible for those flood scenarios to which they apply.
HLR-IFHR-E	Documentation of the Internal Flood Human Reliability Analysis shall provide traceability of the analysis.

Table 3-2.6-2 Supporting Requirements for HLR-IFHR-A

The internal flood PRA shall identify human actions relevant to the accident sequences in the Internal Flood PRA Plant Response Analysis (HLR-IFHR-A).

Index No. IFHR-A	Capability Category I	Capability Category II
IFHR-A1	REVIEW all post-initiator HFEs in the internal-events PRA model to determine whether each operator action remains relevant in the context of the internal flood PRA consistent with the plant response model for the internal flood events and their associated scenarios per the Internal Flood PRA Plant Response Analysis requirements in this Part. In determining the applicability of operator actions from the internal-events PRA, SATISFY the CC-I requirements in HLR-HR-E in Part 2 for Human Reliability Analysis except where the requirements are not applicable.	REVIEW all post-initiator HFEs in the internal-events PRA model to determine whether each operator action remains relevant in the context of the internal flood PRA consistent with the plant response model for the internal flood events and their associated scenarios per the Internal Flood PRA Plant Response Analysis requirements in this Part. In determining the applicability of operator actions from the internal-events PRA, SATISFY the CC-II requirements in HLR-HR-E in Part 2 for Human Reliability Analysis except where the requirements are not applicable.
IFHR-A2	For internal flood scenarios, IDENTIFY any new internal flood operator actions stated in the plant procedures in a manner consistent with the plant response model for the internal flood events and their associated scenarios per the Internal Flood PRA Plant Response Analysis requirements in this Part. For any new operator actions identified, SATISFY the CC-I requirements in HLR-HR-E in Part 2 for Human Reliability Analysis except where the requirements are not applicable.	For internal flood scenarios, IDENTIFY any new internal flood operator actions stated in the plant procedures in a manner consistent with the plant response model for the internal flood events and their associated scenarios per the Internal Flood PRA Plant Response Analysis requirements in this Part. For any new operator actions identified, SATISFY the CC-II requirements in HLR-HR-E in Part 2 for Human Reliability Analysis except where the requirements are not applicable. For the internal flood events and their associated scenarios per the plant response model, IDENTIFY any undesired operator actions (e.g., terminating a mitigation action) that could result from failures of indicators and annunciators caused by internal flood-induced failure mechanisms.

Table 3-2.6-3 Supporting Requirements for HLR-IFHR-B

The internal flood PRA shall include HFEs in the Internal Flood PRA Plant Response Analysis (HLR-IFHR-B).

Index No. IFHR-B	Capability Category I	Capability Category II
IFHR-B1	INCLUDE and, if necessary, MODIFY HFEs corresponding to the operator actions identified per SR IFHR-A1 in the Internal Flood PRA Plant Response Analysis in a manner consistent with the modeling, such that the HFEs represent the impact of human failures at the function, system, train, or component level as appropriate.	
IFHR-B2	INCLUDE new internal flood-related HFEs corresponding to the actions identified per SR IFHR-A2 and SATISFY the CC-I requirements in HLR-HR-F in Part 2 for Human Reliability Analysis except where the requirements are not applicable.	INCLUDE new internal flood-related HFEs corresponding to the actions identified per SR IFHR-A2 and SATISFY the CC-II requirements in HLR-HR-F in Part 2 for Human Reliability Analysis except where the requirements are not applicable.
IFHR-B3	COMPLETE the definition of the HFEs identified in SR IFHR-B1 and SR IFHR-B2 including the relevant internal flood-related context presented by the internal flood events in the PRA at a high level (e.g., sufficient to provide the context needed for a screening HRA). For the definitions of HFEs, SATISFY the CC-I requirements in HLR-HR-F in Part 2 except where the requirements are not applicable.	COMPLETE the definition of the HFEs identified in SR IFHR-B1 and SR IFHR-B2 including the relevant internal flood-related context presented by the internal flood events in the PRA. For the definitions of HFEs, SATISFY the CC-II requirements in HLR-HR-F in Part 2 except where the requirements are not applicable.

Table 3-2.6-4 Supporting Requirements for HLR-IFHR-C

The internal flood PRA shall quantify HEPs accounting for the plant-specific and scenario-specific influences on human performance, particularly including the effects of internal floods, and addressing potential dependencies (HLR-IFHR-C).

Index No. IFHR-C	Capability Category I	Capability Category II
IFHR-C1	CALCULATE the HEPs for all HFEs by addressing relevant internal flood-related effects using conservative estimates (e.g., screening values). For the calculations of HEPs, SATISFY the CC-I requirements in HLR-HR-G in Part 2 for Human Reliability Analysis except where the requirements are not applicable.	CALCULATE the HEPs for all HFEs by addressing relevant internal flood-related effects using detailed analyses for the HFEs that are risk-significant contributors. For the calculations of HEPs, SATISFY the CC-II requirements in HLR-HR-G in Part 2 for Human Reliability Analysis except where the requirements are not applicable.

Table 3-2.6-5 Supporting Requirements for HLR-IFHR-D

The internal flood PRA shall include recovery actions only if it has been demonstrated that the actions are plausible and feasible for those flood scenarios to which they apply (HLR-IFHR-D).

Index No. IFHR-D	Capability Category I	Capability Category II
IFHR-D1	IDENTIFY internal flood-specific operator recovery actions and meet SR HR-H1 in Part 2 for Human Reliability Analysis. QUANTIFY the corresponding HEP values including relevant internal flood-related effects and any effects that may preclude a recovery action or alter the manner in which it is accomplished and meet SR HR-H2 and SR HR-H3 for Human Reliability Analysis in Part 2 except where the requirements are not applicable.	
IFHR-D2	IDENTIFY the sources of model uncertainty, the related assumptions, and reasonable alternatives associated with the Internal Flood Human Reliability Analysis in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 3-2.6-6 Supporting Requirements for HLR-IFHR-E

Documentation of the Internal Flood Human Reliability Analysis shall provide traceability of the analysis (HLR-IFHR-E).

Index No. IFHR-E	Capability Category I	Capability Category II
IFHR-E1	DOCUMENT the process used in the Internal Flood Human Reliability Analysis specifying what is used as input, the applied methods, and the results. The documentation includes, as a minimum, *(a)* the identification of HFEs, including those carried over from the internal-events PRA, new internal flood-specific human actions, recovery actions, and undesired operator actions *(b)* those internal flood-related influences that affect the methods, processes, or assumptions used *(c)* flood area-specific and internal flood scenario-specific performance shaping factors for the HFEs identified *(d)* procedural guidance, training, and plant practice for the operator actions evaluated *(e)* quantification of HEPs *(f)* meeting the documentation requirements in HLR-HR-I for Human Reliability Analysis in Part 2 except where the requirements are not applicable	
IFHR-E2	DOCUMENT the sources of model uncertainty, the related assumptions, and reasonable alternatives (as identified via SR IFHR-D2) associated with the Internal Flood Human Reliability Analysis.	

3-2.7 INTERNAL FLOOD RISK QUANTIFICATION (IFQU)

3-2.7.1 Objectives

The objectives of Internal Flood Risk Quantification are to quantify the internal flood-induced CDF and LERF and document the analysis in a way such that

(a) flood-induced equipment failures and failures due to independent causes are included in the accident sequence quantification

(b) risk-significant contributors to internal flood-induced CDF and LERF, including flood-induced initiating events, accident sequences, and basic events are identified, evaluated, and understood in the context of the plant design, operation, and maintenance

(c) analysis limitations and uncertainties are understood

(d) the Internal Flood Risk Quantification is documented to provide traceability of the analysis

Table 3-2.7-1 High Level Requirements for Internal Flood Risk Quantification (IFQU)

Designator	Requirement
HLR-IFQU-A	The internal flood-induced CDF shall be quantified.
HLR-IFQU-B	The internal flood-induced CDF quantification shall use appropriate models and codes and a truncation level sufficiently low to show convergence and shall address method-specific limitations and features.
HLR-IFQU-C	Model quantification shall determine that all identified dependencies (including operator actions) are addressed appropriately.
HLR-IFQU-D	The internal flood-induced LERF shall be quantified.
HLR-IFQU-E	The internal flood-induced CDF and LERF quantification results shall be reviewed for correctness, completeness, and consistency. The risk-significant contributors to CDF and LERF, such as internal floods and their corresponding plant-initiating events, internal flood areas, accident sequences, basic events (equipment unavailabilities and HFEs), plant damage states, containment challenges, and failure modes, shall be identified. The results shall be traceable to the inputs and assumptions made in the internal flood PRA.
HLR-IFQU-F	Uncertainties in the internal flood PRA results shall be characterized. Sources of model uncertainty and related assumptions shall be identified and their potential impact on the results understood.
HLR-IFQU-G	Documentation of the Internal Flood Risk Quantification shall provide traceability of the analysis and interpretation of the risk profile for the plant.

Table 3-2.7-2 Supporting Requirements for HLR-IFQU-A

The internal flood-induced CDF shall be quantified (HLR-IFQU-A).

Index No. IFQU-A	Capability Category I	Capability Category II
IFQU-A1	INCLUDE, in the quantification, accident sequences comprising failures caused by the flood and those due to independent causes, including equipment failures, unavailability due to maintenance, common cause failures, and other credible causes that may reduce the plant capabilities to mitigate the flood-induced initiating event.	
IFQU-A2	INCLUDE, in the quantification, both the direct effects of the flood (e.g., loss of cooling from a service water train due to an associated pipe rupture) and spatial effects such as submergence, jet impingement, spray, harsh environment, and pipe whip, as applicable.	
IFQU-A3	If additional analysis of SSC data is required to support quantification of flood-induced accident sequences, PERFORM the necessary data analysis, and SATISFY the CC-I requirements in HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D for Data Analysis in Part 2 except where the requirements are not applicable.	If additional analysis of SSC data is required to support quantification of flood-induced accident sequences, PERFORM the necessary data analysis and SATISFY the CC-II requirements in HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D for Data Analysis in Part 2 except where the requirements are not applicable.
IFQU-A4	CALCULATE the internal flood-induced CDF, on a reactor-year basis, using the flood-induced accident sequences, and meet the CC-I requirements in HLR-QU-A in Part 2 for quantification except where the requirements are not applicable. INCLUDE the scenario-specific quantification factors (e.g., the HEPs obtained per the Internal Flood Human Reliability Analysis).	CALCULATE the internal flood-induced CDF, on a reactor-year basis, using the flood-induced accident sequences, and meet the CC-II requirements in HLR-QU-A in Part 2 for quantification except where the requirements are not applicable. INCLUDE the scenario-specific quantification factors (e.g., the HEPs obtained per the Internal Flood Human Reliability Analysis).
IFQU-A5	RETAIN internal flood scenarios in the final internal flood PRA CDF model unless it can be concluded that SCR-2 from Table 1-1.8-1 is directly met.	
IFQU-A6	COLLECT inputs to the following analyses, which support quantifications of flood-induced accident sequences, from plant-information sources or via plant walkdown(s): *(a)* engineering analyses *(b)* human reliability analyses *(c)* spray or other applicable impact assessments *(d)* screening decisions CONFIRM the accuracy of information collected by conducting walkdown(s).	
IFQU-A7	IDENTIFY the sources of model uncertainty, the related assumptions, and reasonable alternatives associated with the internal flood accident sequences and quantification in a manner that supports the applicable requirements of Table 2-2.7-6 (HLR-QU-E).	

Table 3-2.7-3 Supporting Requirements for HLR-IFQU-B

The internal flood-induced CDF quantification shall use appropriate models and codes and a truncation level sufficiently low to show convergence and shall address method-specific limitations and features (HLR-IFQU-B).

Index No. IFQU-B	Capability Category I	Capability Category II
IFQU-B1	For the quantification of internal flood-induced CDF, SATISFY the requirements in HLR-QU-B for quantification except where the requirements are not applicable.	

Table 3-2.7-4 Supporting Requirements for HLR-IFQU-C

Model quantification shall determine that all identified dependencies (including operator actions) are addressed appropriately (HLR-IFQU-C).

Index No. IFQU-C	Capability Category I	Capability Category II
IFQU-C1	INCLUDE dependencies during the internal flood PRA model quantification and SATISFY the requirements in HLR-QU-C for quantification except where the requirements are not applicable.	

Table 3-2.7-5 Supporting Requirements for HLR-IFQU-D

The internal flood-induced LERF shall be quantified (HLR-IFQU-D).

Index No. IFQU-D	Capability Category I	Capability Category II
IFQU-D1	CALCULATE LERF, on a reactor-year basis, using the internal flood PRA model, and SATISFY the CC-I requirements in HLR-LE-E in Part 2 for LERF Analysis except where the requirements are not applicable, with the following clarifications: *(a)* CC-I SRs in SR LE-E1 in Part 2 are to be met in a manner consistent with the applicable requirements of Section 3-2.6 and SR IFQU-A3 *(b)* SR LE-E4, including the "Discussion" for that SR in Part 2, is to be met consistent with SR IFQU-A4, SR IFQU-B1, and SR IFQU-C1	CALCULATE LERF, on a reactor-year basis, using the internal flood PRA model, and SATISFY the CC-II requirements in HLR-LE-E in Part 2 for LERF Analysis except where the requirements are not applicable, with the following clarifications: *(a)* CC-II SRs in SR LE-E1 in Part 2 are to be met in a manner consistent with the applicable requirements of Section 3-2.6 and SR IFQU-A3 *(b)* SR LE-E4, including the "Discussion" for that SR in Part 2, is to be met consistent with SR IFQU-A4, SR IFQU-B1, and SR IFQU-C1
IFQU-D2	RETAIN internal flood scenarios in the final internal flood PRA LERF model unless it can be concluded that the LERF screening criteria in SCR-2 from Table 1-1.8-1 is directly met.	

Table 3-2.7-6 Supporting Requirements for HLR-IFQU-E

The internal flood-induced CDF and LERF quantification results shall be reviewed for correctness, completeness, and consistency. The risk-significant contributors to CDF and LERF, such as internal floods and their corresponding plant-initiating events, internal flood areas, accident sequences, basic events (equipment unavailabilities and HFEs), plant damage states, containment challenges, and failure modes, shall be identified. The results shall be traceable to the inputs and assumptions made in the internal flood PRA (HLR-IFQU-E).

Index No. IFQU-E	Capability Category I	Capability Category II
IFQU-E1	IDENTIFY risk-significant contributors, and SATISFY the CC-I requirements in HLR-QU-D, SR LE-F1, and SR LE-F2 except where the requirements are not applicable, with the following clarifications: *(a)* CC-I SRs in SR QU-D6 in Part 2 are to be met, including identification of which internal flood scenarios and which flood areas (consistent with the level of resolution of the internal flood PRA such as internal flood areas) are risk-significant contributors. *(b)* SR QU-D7 in Part 2 is to be met, recognizing that "component" in Part 2 is generally equivalent to "equipment" in Part 3. *(c)* SR QU-D4 for comparison to similar plants is not applicable.	IDENTIFY risk-significant contributors, and SATISFY the CC-II requirements in HLR-QU-D, SR LE-F1, and SR LE-F2 except where the requirements are not applicable, with the following clarifications: *(a)* CC-II SRs in SR QU-D6 in Part 2 are to be met, including identification of which internal flood scenarios and which flood areas (consistent with the level of resolution of the internal flood PRA such as internal flood areas) are risk-significant contributors. *(b)* SR QU-D7 in Part 2 is to be met, recognizing that "component" in Part 2 is generally equivalent to "equipment" in Part 3. *(c)* SR QU-D4 for comparison to similar plants is not applicable.

Table 3-2.7-7 Supporting Requirements for HLR-IFQU-F

Uncertainties in the internal flood PRA results shall be characterized. Sources of model uncertainty and related assumptions shall be identified and their potential impact on the results understood (HLR-IFQU-F).

Index No. IFQU-F	Capability Category I	Capability Category II
IFQU-F1	ASSESS the impact of the model uncertainties and related assumptions identified for each technical element (SR IFPP-B5, SR IFSO-A8, SR IFSN-A18, SR IFEV-B6, SR IFPR-B11, SR IFHR-D2, and SR IFQU-A7) by qualitatively or quantitatively estimating the extent to which the results (e.g., internal flood-induced CDF/LERF, accident sequences, contributors) would change.	
IFQU-F2	PERFORM an uncertainty analysis for the CDF and LERF of the internal flood PRA and SATISFY the CC-I requirements in HLR-QU-E in Part 2 for Quantification and SR LE-F3 in Part 2 for LERF Analysis except where the requirements are not applicable.	PERFORM an uncertainty analysis for the CDF and LERF of the internal flood PRA and SATISFY the CC-II requirements in HLR-QU-E in Part 2 for Quantification and SR LE-F3 in Part 2 for LERF Analysis except where the requirements are not applicable.

Table 3-2.7-8 Supporting Requirements for HLR-IFQU-G

Documentation of the Internal Flood Risk Quantification shall provide traceability of the analysis and interpretation of the risk profile for the plant (HLR-IFQU-G).

Index No. IFQU-G	Capability Category I	Capability Category II
IFQU-G1	DOCUMENT the process used in the Internal Flood Risk Quantification specifying what is used as input, the applied methods, and the results. The documentation includes, as a minimum, *(a)* the internal flood-induced CDF and LERF quantification process, including any screening performed *(b)* the results of the internal flood-induced CDF and LERF quantification *(c)* importance measures *(d)* uncertainty interval from propagation of parametric uncertainties *(e)* description of the revised and new data analyses used to support the quantification of the internal flood-induced accident sequence model *(f)* meeting the documentation requirements in SR QU-F1, SR QU-F2, SR LE-G1, SR LE-G2, SR DA-E1, and SR DA-E2 in Part 2 except where the requirements are not applicable	
IFQU-G2	DOCUMENT the risk-significant contributors (e.g., initiating events, accident sequences, cutsets, basic events, flood areas, flood sources, operator actions) to internal flood-induced CDF and LERF in the PRA results summary. DESCRIBE risk-significant accident sequences or functional failure groups in accordance with the definitions provided in Section 1-2.2.	
IFQU-G3	DOCUMENT the sources of model uncertainty, the related assumptions, and reasonable alternatives (as identified in SR IFQU-A7, SR IFQU-F1, and SR IFQU-F2) associated with the internal flood accident sequences and quantification.	
IFQU-G4	DOCUMENT limitations in the Internal Flood Risk Quantification process that would impact applications.	

NONMANDATORY APPENDIX 3-A
INTERNAL FLOOD AT-POWER PRA: COMMENTARY

3-A.1 INTRODUCTION AND OVERVIEW

This Nonmandatory Appendix (NMA) provides notes and general explanatory material tied to specific SRs as stated in Part 3 of this Standard. The material contained in this Appendix is nonmandatory and, as such, does not establish new requirements: rather, the material is intended to clarify the intent of an SR, explain terminologies that might be used in an SR, and/or provide examples of analysis approaches that would meet the intent of the SR.

The scope of the flooding events addressed in this Part includes all flood scenarios originating within the plant boundary. It does not include floods resulting from external events (e.g., weather or off-site events such as upstream dam rupture).

The overall objective of the internal flood PRA is to ensure that the impact of internal flood as the cause of either an accident or a system failure is evaluated in such a way that

(a) the flood sources within the plant that could flood plant locations or create adverse conditions (e.g., submersion, spray, elevated temperature, humidity, pressure, pipe whip, jet impingement) and thereby damage mitigative plant equipment are identified

(b) the flood-induced accident sequences that contribute to the CDF and LERF are identified and quantified[1]

A set of technical elements and associated requirements is provided for the internal flooding hazard group in this Standard. Because there are many different sources of floods throughout the plant, with different potential impact on SSCs, there is the potential for a relatively large number of individual flood scenarios and flood-induced accident sequences with unique spatial dependencies. Although it is optional, some degree of screening out of flood-induced scenarios and accident sequences is typically employed in analyzing risk from internal floods, so that, although the HLRs and SRs are written in a discrete manner, the requirements are not necessarily presented in sequential order of application; in some cases, they must be considered jointly, so that screening out is performed appropriately. Thus, to determine the degree to which a particular SR is to be met, it is necessary to consider the degree to which other, related requirements (some of which may be under other HLRs) are being addressed. Screening out is typically employed at the flood-area, flood-source, or flood-scenario level with the understanding that screening out of areas and sources includes the relevant flood scenarios associated with the area or source.

An internal flood PRA need not be performed at a uniform level of detail. The analyses performed to support the screened-out flood areas may be performed at a less rigorous and/or less complete level than analyses performed for flood areas, flood sources, and/or flood scenarios that are retained (i.e., not screened out) and thus require further analysis. An iterative process is also common in internal flood PRAs. Those flood areas that represent the higher-risk contributors may be analyzed repeatedly, each time incorporating additional detail for specific aspects of the analysis (e.g., flood source and propagation modeling, credit for drains or mitigation, refinements to the internal flood PRA plant response model, and the HRA). At any stage, the additional detail may allow for the screening out of a flood area. It is intended that this Standard allows for analysis flexibility in this regard. As such, the level of detail and resolution for lower-risk and/or screened-out flood areas may be lower than for higher-risk flood areas, which are retained, without affecting the capability of the internal flood PRA to identify flood-induced accident sequences that are risk-significant contributors. For example, a service building containing numerous flood sources may be analyzed as a single flood area and analyzed for screening purposes. If the building can be screened out (e.g., it contains no equipment modeled in the other portions of the PRA and there are no propagation paths to other buildings), then the overall categorization of the internal flood PRA is unaffected. Similarly, the requirements for developing specific internal flood scenarios, detailed HRA, and so on are not needed for screened-out flood areas and may not be needed for lower-risk flood areas that are retained as long as the overall validity of the final results is unaffected.

Walkdowns are typically performed to confirm the accuracy of the following information obtained from

[1] In this Part of this Standard, "internal flood" is used as a modifier (e.g., "internal flood-induced") in several HLRs and SRs as a shorthand way of indicating that in meeting the requirement, consideration should be given to applicable flood-induced causes of SSC failure (e.g., submersion, spray, elevated temperature, humidity, pressure, pipe whip, jet impingement) and resulting flood-induced failure mechanisms. Applicability of the various flood-induced causes of SSC failure and resulting failure mechanisms to a particular requirement may need to be determined based on consideration of related supporting requirements.

plant information sources and used in the internal flood PRA:

(a) the documented spatial information and plant design features that support the development of flood areas

(b) the documented locations of flood sources

(c) the appropriateness of the documented flood scenarios

(d) the feasibility of operator actions to mitigate the internal flood

(e) the appropriateness of spray or other impact assessment and engineering analyses used in the quantification

In accordance with the application process described in Section 1-3, the Capability Categories required for various aspects of the internal flood PRA are determined by the intended PRA application and may not be uniform across all aspects of the internal flood PRA.

The following PRA technical elements are included in the internal flood PRA process:

(a) Internal Flood Plant Partitioning (IFPP)

(b) Internal Flood Source Identification and Characterization (IFSO)

(c) Internal Flood Scenario Development (IFSN)

(d) Internal Flood Initiating Event Analysis (IFEV)

(e) Internal Flood PRA Plant Response Analysis (IFPR)

(f) Internal Flood Human Reliability Analysis (IFHR)

(g) Internal Flood Risk Quantification (IFQU)

Example approaches to performing each of the technical elements of an internal flood PRA may be found in EPRI 1019194 [3-A-1].

3-A.2 COMMENTARY TO INTERNAL FLOOD PRA TECHNICAL ELEMENTS AND REQUIREMENTS

3-A.2.1 COMMENTARY TO INTERNAL FLOOD PLANT PARTITIONING (IFPP)

The Internal Flood Plant Partitioning technical element defines the physical boundaries of the analysis (i.e., the locations within the plant where flood scenarios are postulated) and divides the various volumes within that boundary into physical analysis units referred to as "flood areas."

The plant partitioning analysis should ensure the following:

(a) The overall analysis boundary is appropriate for the internal flood PRA scope.

(b) The criteria used to partition the plant into physical analysis units (flood areas) are defined and appropriate.

(c) The physical analysis units (flood areas) are identified and described.

(d) The walkdown confirms the accuracy of the information obtained from plant information sources to assess spatial information and plant design features that support the development of flood areas.

Table 3-A.2.1-1 Commentary to High Level Requirements for Internal Flood Plant Partitioning (IFPP)

Designator	Commentary
HLR-IFPP-A	This HLR requires the definition of the analysis boundary for the internal flood PRA. All plant areas or locations within the licensee-controlled area should be included in the analysis unless justified to not impact the internal flood PRA.
HLR-IFPP-B	This HLR requires the definitions of the flood areas used for the internal flood PRA. Flood areas should be defined by physical characteristics that separate an area from other areas by barriers that delay, restrict, or prevent propagation of floods to adjacent areas.
HLR-IFPP-C	No commentary provided.

Table 3-A.2.1-2 Commentary to Supporting Requirements for HLR-IFPP-A

Index No. IFPP-A	Commentary
IFPP-A1	This SR requires the definition of the analysis boundary for the internal flood PRA. It involves the screening out of areas within the licensee-controlled area that would not impact the risk resulting from the internal flood scenarios. For any areas that are screened out, a justification must be provided to demonstrate that an internal flood could not adversely affect any equipment to be included in the internal flood PRA plant response model. Exclusions from the plant analysis boundary must be documented according to SR IFPP-C1.

Table 3-A.2.1-3 Commentary to Supporting Requirements for HLR-IFPP-B

Index No. IFPP-B	Commentary
IFPP-B1	This SR requires the definition of the flood areas within the internal flood analysis boundary that are used for the internal flood PRA analysis. The physical characteristics that are used to define flood areas may include walls (watertight or nonwatertight), partial-height walls, doors (watertight or nonwatertight), hatches, berms, dikes, or curbs.
IFPP-B2	The most current plant information should be used in the definitions of flood areas. Plant information sources used to support the definitions of flood areas may include plant layout drawings, piping and instrumentation diagrams, design basis flood calculation documents, and fire area analysis documents.
IFPP-B3	No commentary provided.
IFPP-B4	Walkdowns are performed to confirm the accuracy or correctness of information obtained from plant sources and collect additional information that cannot be easily obtained from plant sources. Walkdown(s) may be performed in conjunction with SR IFSO-A7, SR IFSN-A17, and SR IFQU-A6. When determining the scope and details of the walkdown, it is important that the intent of the walkdown be considered. The intent is to identify items that invalidate modeling in the PRA to such an extent that the model does not reasonably represent the as-built, as-operated plant. In keeping with this intent, it is acceptable that conditions that can be justified as not likely to affect the results (i.e., will not change the risk profile or insights) do not need to be validated. As such, and per Inquiry 20-2435 [3-A-2], it is not required that 100% walkdown be performed if adequate justification can be provided that a lesser scope will suffice. Various justifications could be considered valid, but they must show that *(a)* items that could have a significant impact were walked down and *(b)* those items not walked down could not have a significant impact. The following are examples of possible justifications: *(a) Bounding Risk Impact*: If the importance measure of an item is low, such that even if the item were assumed failed all the time, the PRA results would not meaningfully change. *(b) Adequacy of Documentation*: There is a sufficient weight of evidence, through drawings, photos/videos, analyses, or interviews with knowledgeable plant staff, that the conditions are as assumed in the PRA. *(c) Impact of Possible Discoveries*: Given past experience with the types of deviations typically found during walkdowns, it is not credible or likely that a deviation would be found that could affect the conditions assumed in the PRA to the extent required to meaningfully change the results.
IFPP-B5	Reasonable alternatives are associated with the assumptions made in the development of the plant partitioning analysis. Examples of assumptions where reasonable alternatives could be developed include assumptions about any areas excluded from within the licensee-controlled area, assumptions about how physical barriers are used to divide flood areas, or assumptions about how adjacent unit areas are defined for multi-unit sites. Source of model uncertainty is defined in Section 1-2.2.

Table 3-A.2.1-4 Commentary to Supporting Requirements for HLR-IFPP-C

Index No. IFPP-C	Commentary
IFPP-C1	An example method to demonstrate that this SR is satisfied is a cross-reference identifying each SR and where it is addressed in the documentation. This example of a documentation method facilitates PRA applications, upgrades, and peer reviews. Key findings from walkdown(s) should be included as part of the walkdown documentation. Note that documenting the basis for nonapplicability demonstrates that all applicable requirements in Part 2 were reviewed and dispositioned accordingly. See entry for SR IFPP-A1 in this Appendix for discussion of reasons for excluding any areas within the licensee-controlled area from further analysis. Examples of a flood area include a room with enclosed walls and door, a portion of an area separated from other parts of the area with a curb.
IFPP-C2	Source of model uncertainty is defined in Section 1-2.2.

3-A.2.2 COMMENTARY TO INTERNAL FLOOD SOURCE IDENTIFICATION AND CHARACTERIZATION (IFSO)

In the Internal Flood Source Identification and Characterization technical element, the various potential sources of floods within the plant are identified, along with the mechanisms resulting in flood from these sources, and a characterization of the flood sources (e.g., amount of liquid, flow rates) is made.

The Internal Flood Source Identification and Characterization should ensure the following:

(a) The potential flood sources have included equipment located in flood areas that are connected to fluid systems, internal sources, and external sources that are connected to the flood areas.

(b) The flooding mechanisms have included pressure boundary failure and human-induced events that result in releases in the flood area.

(c) The flood areas screened out do not contain potential flood sources and do not serve as a propagation path to other flood areas. The screening criteria have been uniformly applied, and flood areas that are risk-significant contributors are included.

(d) The flood source and corresponding release mechanisms have been appropriately characterized.

(e) A walkdown is required to confirm the accuracy of the information obtained from plant information sources to assess the location of flood sources.

Table 3-A.2.2-1 Commentary to High Level Requirements for Internal Flood Source Identification and Characterization (IFSO)

Designator	Commentary
HLR-IFSO-A	This HLR requires the identification and characterization of the internal flood sources considered in the internal flood PRA.
HLR-IFSO-B	This HLR requires the documentation of the identification and characterization of the internal flood sources.

Table 3-A.2.2-2 Commentary to Supporting Requirements for HLR-IFSO-A

Index No. IFSO-A	Commentary
IFSO-A1	Examples of fluid systems include circulating water system, service water system, component cooling water system, fire protection system, feedwater system, condensate and steam systems, reactor coolant system, and other high-energy lines.
IFSO-A2	The flooding hazard considered in the scope of the internal flood PRA for the oil sources is only the wetting hazard. The internal flood PRA only considers the unignited portion of the oil release scenarios. The ignited portion of the oil release scenarios is treated in Part 4. Therefore, there is no overlap between the internal flood PRA and internal fire PRA for the oil release scenarios. Typically, oil is qualitatively screened out in the internal flood PRA, and no quantitative analysis is required (i.e., no need for oil system failure/rupture frequencies). If quantification of the oil system failure/rupture is needed, there are data sources in other industries (oil and gas) for the oil-containing systems. The unignited, wetting hazard of the oil release is included in Part 3 (as an internal hazard) and not in Part 6 or Part 9 because those Parts address other types of hazards. Analysis considerations for the wetting hazard from the oil system are essentially the same as those for the water systems.
IFSO-A3	No commentary provided.
IFSO-A4	This SR involves the screening out of flood areas as flood-initiating areas based on the absence of flood sources. A flood area containing no flood sources would not be a flood-initiating area. However, a flood area without flood sources may still need to be retained in a flood scenario because it may be a part of a flood propagation path, and in some cases the flood area may contain PRA SSCs susceptible to flood damage.
IFSO-A5	This SR involves the identification of the causes or mechanisms that can lead to the various flood hazards.
IFSO-A6	No commentary provided.
IFSO-A7	Walkdowns are performed to confirm the accuracy or correctness of information obtained from plant sources and collect additional information that cannot be easily obtained from plant sources. Walkdown(s) may be performed in conjunction with SR IFPP-B4, SR IFSN-A17, and SR IFQU-A6. When determining the scope and details of the walkdown, it is important that the intent of the walkdown be considered. The intent is to identify items that invalidate modeling in the PRA to such an extent that the model does not reasonably represent the as-built, as-operated plant. In keeping with this intent, it is acceptable that conditions that can be justified as not likely to affect the results (i.e., will not change the risk profile or insights) do not need to be validated. As such, and per Inquiry 20-2435 [3-A-2], it is not required that 100% walkdown be performed if adequate justification can be provided that a lesser scope will suffice. Various justifications could be considered valid, but they must show that *(a)* items that could have a significant impact were walked down and *(b)* those items not walked down could not have a significant impact. The following are examples of possible justifications: *(a)* *Bounding Risk Impact*: If the importance measure of an item is low, such that even if the item were assumed failed all the time, the PRA results would not meaningfully change. *(b)* *Adequacy of Documentation*: There is a sufficient weight of evidence, through drawings, photos/videos, analyses, or interviews with knowledgeable plant staff, that the conditions are as assumed in the PRA. *(c)* *Impact of Possible Discoveries*: Given past experience with the types of deviations typically found during walkdowns, it is not credible or likely that a deviation would be found that could affect the conditions assumed in the PRA to the extent required to meaningfully change the results.
IFSO-A8	Reasonable alternatives are associated with the assumptions made in the identification and characterization of internal flood sources. Source of model uncertainty is defined in Section 1-2.2.

Table 3-A.2.2-3 Commentary to Supporting Requirements for HLR-IFSO-B

Index No. IFSO-B	Commentary
IFSO-B1	An example method to demonstrate that this SR is satisfied is a cross-reference identifying each SR and where it is addressed in the documentation. This example of a documentation method facilitates PRA applications, upgrades, and peer reviews. Key findings from walkdown(s) should be included as part of the walkdown documentation. Note that documenting the basis for nonapplicability demonstrates that all applicable requirements in Part 2 were reviewed and dispositioned accordingly.
IFSO-B2	Source of model uncertainty is defined in Section 1-2.2.

3-A.2.3 COMMENTARY TO INTERNAL FLOOD SCENARIO DEVELOPMENT (IFSN)

In the Internal Flood Scenario Development technical element, a set of flood scenarios is developed, relating flood source, propagation path(s), and affected equipment.

The Internal Flood Scenario Development should ensure the following:

(a) For a selected set of flood areas and corresponding flood sources, the potential propagation paths have been identified, and plant design features capable of containing or terminating flood propagation are included and appropriately credited.

(b) For a selected set of potential propagation paths, the SSCs along each propagation path represent those that are included in the internal-events PRA model, are required to respond to an initiating event or whose failure would challenge plant operation, and are susceptible to flood damage.

(c) The capacity of drains is estimated to determine flood volume and potential impact on PRA-related SSCs.

(d) The susceptibility of SSCs in a selected set of flood areas is determined, and failure of SSCs caused by submergence and spray is considered in the determination process. Flood-induced failure mechanisms other than submergence or spray are assessed.

(e) For a selected set of flood scenarios, the associated flood area and flood source, characteristics of the release, operator actions, and SSCs impacted along the propagation paths are used to develop and define each scenario in a consistent manner.

(f) For a selected set of flood scenarios, the associated calculations include flood source inventory, release rates, propagation pathways, barrier failures, and maximum or critical flood heights for susceptible SSCs in each affected flood area to ensure reasonable characterization of the flood consequence.

(g) The flood areas and flood sources screened out are properly identified, and the bases for screening are applied appropriately.

(h) A walkdown is required to confirm the accuracy of the information obtained from plant information sources to assess the appropriateness of flood scenarios.

Table 3-A.2.3-1 Commentary to High Level Requirements for Internal Flood Scenario Development (IFSN)

Designator	Commentary
HLR-IFSN-A	This HLR requires that all potentially risk-significant flood scenarios be defined and characterized, including, for example, identifying the flood source and the corresponding hazard and flooding effect(s), release rate, propagation paths, flood areas impacted, SSCs impacted, and potential operator mitigation action.
HLR-IFSN-B	This HLR requires the documentation of the Internal Flood Scenario Development, and it is important to document the Internal Flood Scenario Development in a manner that facilitates peer reviews and future updates/upgrades.

Table 3-A.2.3-2 Commentary to Supporting Requirements for HLR-IFSN-A

Index No. IFSN-A	Commentary
IFSN-A1	The process of defining flood propagation paths is iterative; therefore, SR IFSN-A1, SR IFSN-A2, and SR IFSN-A3 would normally be applied in parallel and not necessarily sequentially. The identification of flood propagation paths is intended only for those flood sources in flood areas retained from the qualitative screening considered in SR IFSO-A4, SR IFSN-A15, and SR IFSN-A16.
IFSN-A2	Flood barriers are physical structures that allow for the accumulation and retention of water. The process of defining flood propagation paths is iterative; therefore, SR IFSN-A1, SR IFSN-A2, and SR IFSN-A3 would normally be applied in parallel and not necessarily sequentially. The identification of plant design features that support the ability to terminate or contain the flood propagation is intended only for those flood sources in flood areas retained from the qualitative screening considered in SR IFSO-A4, SR IFSN-A15, and SR IFSN-A16.
IFSN-A3	The process of defining flood propagation paths is iterative; therefore, SR IFSN-A1, SR IFSN-A2, and SR IFSN-A3 would normally be applied in parallel and not necessarily sequentially. The identification of automatic actuations or operator responses that have the ability to terminate or contain the flood propagation is intended only for those flood sources in flood areas retained from the qualitative screening considered in SR IFSO-A4, SR IFSN-A15, and SR IFSN-A16.
IFSN-A4	An example of SSC impacts from flooding is whether the SSC would be submerged.
IFSN-A5	Examples of flooding mitigative features may include spray shielding and equipment enclosure ratings for flood or spray proofing.
IFSN-A6	CC-I of this SR considers those internal flood PRA studies that may have limited their scope of analysis including only the flooding effects of submergence and spray.
IFSN-A7	This SR specifies the methods that can be used to justify the conclusion that an SSC is not susceptible to damage by flooding effects.
IFSN-A8	CC-II of this SR includes the consideration of flood propagation through failure of such barriers as normally closed doors, penetration seals, etc.
IFSN-A9	Examples of flood area design features/parameters include flood area dimensions, floor opening dimensions, wall opening dimensions, floor and door gap dimensions, drain sizes, free volume not occupied by SSCs, and SSC critical flood heights. Action verb "CALCULATE" is meant to determine the value of a parameter, variable, quantity, or solution by a mathematical or a more rigorous process, whereas action verb "ESTIMATE" is meant to compute roughly, often from imperfect input data or using a simplified process (the meanings of action verbs are stated in NMA 1-A).
IFSN-A10	The flood height analysis should also account for flood area outflow and consider the timing of barrier failures that provide flow into and out of a flood area.
IFSN-A11	In the calculation of flood propagation flow, selected variables (e.g., resistance coefficient in the drain line) cannot be known accurately. Assuming a conservatively high rate of outflow from a flood area can result in nonconservative flood height calculated in the flood-originating area. Assuming a conservatively low rate of outflow from a flood area can result in nonconservative flood height calculated for the floodwater-receiving area. The flood height analysis should not credit the beneficial failure of barriers (including the assumed failure of non-flood-rated doors or failure of doors at a lower flood height than their loading capacities) to reduce flood height.
IFSN-A12	This SR is intended to identify the inadequacy in flood height analysis that limits the duration of the flood height calculation to a short period of time due to, for example, crediting the assumed success of operator isolation action (e.g., within 30 minutes in some design flood calculations), which is before the maximum flood height is reached or before the critical flood height for flood damage susceptible PRA equipment is reached. Therefore, the duration should be determined by the amount of time it takes to reach the maximum or critical flood height, which varies between different flood locations, flood sources, and so on. For infinite volume water sources, the maximum scenario duration can be established based on a combination of mitigation features and operator intervention that afford a high reliability of success for termination of the flooding event.

Table 3-A.2.3-2 Commentary to Supporting Requirements for HLR-IFSN-A (Cont'd)

Index No. IFSN-A	Commentary
IFSN-A13	In the development of flood scenarios, the possibility of failures of such flood barriers as normally closed doors should also be considered.
IFSN-A14	The focus of this SR is the multi-unit flood scenarios.
IFSN-A15	Flood areas can be qualitatively screened out by using the criteria specified in this SR. Some flood areas may not contain any equipment that, if damaged by a flood, can lead to an initiating event or impact the mitigation function(s) required in response to a flooding event. However, these flood areas can still participate as an area through which the flood water can propagate from one flood area to another. These flood areas should be retained for this purpose only. The use and extent of screening out of flood areas is optional. To facilitate an efficient qualitative screening process, conservative representations of the flood impact may be used for screening purposes (e.g., bounding assumptions on flood rate, flood volume, barrier effectiveness, mitigation, and SSC susceptibility to flood-induced failure mechanisms). This requirement recognizes that, to facilitate an efficient screening process, flood areas may be screened out prior to the task of enumerating all relevant flood scenarios for each source and area.
IFSN-A16	Examples of flood mitigation systems include drains and sump pumps. Flood sources can be screened out by using the criteria specified in this SR. The use and extent of screening out of flood sources is optional. To facilitate an efficient qualitative screening process, conservative representations of the flood impact may be used for screening purposes (e.g., bounding assumptions on flood rate, flood volume, barrier effectiveness, mitigation, and SSC susceptibility to flood-induced failure mechanisms). This requirement recognizes that, to facilitate an efficient screening process, flood sources may be screened out prior to the task of enumerating all relevant flood scenarios for each source and area.
IFSN-A17	Examples of mitigative features of SSC include drains and shields. Walkdowns are performed to verify the accuracy or correctness of information obtained from plant sources and collect additional information that cannot be easily obtained from plant sources. Walkdown(s) may be performed in conjunction with SR IFPP-B4, SR IFSO-A7, and SR IFQU-A6. When determining the scope and details of the walkdown, it is important that the intent of the walkdown be considered. The intent is to identify items that invalidate modeling in the PRA to such an extent that the model does not reasonably represent the as-built, as-operated plant. In keeping with this intent, it is acceptable that conditions that can be justified as not likely to affect the results (i.e., will not change the risk profile or insights) do not need to be validated. As such, and per Inquiry 20-2435 [3-A-2], it is not required that 100% walkdown be performed if adequate justification can be provided that a lesser scope will suffice. Various justifications could be considered valid, but they must show that *(a)* items that could have a significant impact were walked down and *(b)* those items not walked down could not have a significant impact. The following are examples of possible justifications: *(a)* *Bounding Risk Impact*: If the importance measure of an item is low, such that even if the item were assumed failed all the time, the PRA results would not meaningfully change. *(b)* *Adequacy of Documentation*: There is a sufficient weight of evidence, through drawings, photos/videos, analyses, or interviews with knowledgeable plant staff, that the conditions are as assumed in the PRA. *(c)* *Impact of Possible Discoveries*: Given past experience with the types of deviations typically found during walkdowns, it is not credible or likely that a deviation would be found that could affect the conditions assumed in the PRA to the extent required to meaningfully change the results.
IFSN-A18	Reasonable alternatives are associated with the assumptions made in the development of the flood scenarios. Source of model uncertainty is defined in Section 1-2.2.

Table 3-A.2.3-3 Commentary to Supporting Requirements for HLR-IFSN-B

Index No. IFSN-B	Commentary
IFSN-B1	An example method to demonstrate that this SR is satisfied is a cross-reference identifying each SR and where it is addressed in the documentation. This example of a documentation method facilitates PRA applications, upgrades, and peer reviews. Additional examples of items that may be included in the documentation are *(a)* key findings from walkdown(s) that are useful in the Internal Flood Scenario Development *(b)* internal flood timelines for those flood mechanisms analyzed in the internal flood PRA Note that documenting the basis for nonapplicability demonstrates that all applicable requirements in Part 2 were reviewed and dispositioned accordingly.
IFSN-B2	Source of model uncertainty is defined in Section 1-2.2.

3-A.2.4 COMMENTARY TO INTERNAL FLOOD INITIATING EVENT ANALYSIS (IFEV)

In the Internal Flood Initiating Event Analysis technical element, the expected plant response(s) to the selected set of flood scenarios is determined, and an initiating event from the internal-events at-power PRA that is reasonably representative of each scenario is selected.

The Internal Flood Initiating Event Analysis should ensure the following:

(a) For a selected set of flood scenarios, the corresponding plant initiating-event group for internal events and failures of SSCs caused by a flood have been identified. New plant initiating-event groups have been developed for flood scenarios that had no corresponding plant initiating-event group for internal events.

(b) The grouping of flood scenarios was performed consistently, and the bases for the groupings included plant response, success criteria, timing, equipment, and operator performance.

(c) For selected scenarios, the flood initiating-event frequencies were estimated by combining plant-specific and generic information. The frequencies for human-induced floods were also estimated.

(d) The flood scenario groups that were screened out were properly identified, and the bases for screening were applied appropriately.

Table 3-A.2.4-1 Commentary to High Level Requirements for Internal Flood Initiating Event Analysis (IFEV)

Designator	Commentary
HLR-IFEV-A	Flooding sources identified as potential risk hazards are associated with a particular initiating event or initiating-event group in order to accurately model the appropriate accident sequence in the PRA model.
HLR-IFEV-B	The initiating-event frequency for a particular flood hazard is quantified using a combination of options including plant-specific data, generic industry data, expert judgment, and so on. Model uncertainties and any related assumptions are captured as part of this HLR.
HLR-IFEV-C	It is important to document the identified internal flood-induced initiating events and their frequencies in a manner that facilitates peer reviews and future updates/upgrades.

Table 3-A.2.4-2 Commentary to Supporting Requirements for HLR-IFEV-A

Index No. IFEV-A	Commentary
IFEV-A1	Grouping of flood scenarios is important when identifying the appropriate initiating-event group(s) and their corresponding accident sequences. Avoid grouping scenarios with dissimilar plant response impacts that are associated with different success criteria.
IFEV-A2	Identification of the corresponding initiating event or initiating-event group for each internal flood scenario or internal flood scenario group can include either transient or loss of coolant accident initiating-event groups, as applicable.
IFEV-A3	No commentary provided.

Table 3-A.2.4-3 Commentary to Supporting Requirements for HLR-IFEV-B

Index No. IFEV-B	Commentary
IFEV-B1	This SR provides an option for the analyst to include in the definition of flood-induced initiating event any automatic or manual actions that can be used for mitigating the effects of a flooding event, provided that the applicable Part 2 SRs are satisfied. Note that documenting the basis for nonapplicability requires that all SRs in HLR-SY-A, HLR-SY-B, and HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D in Part 2 are reviewed and dispositioned accordingly.
IFEV-B2	As part of quantifying the internal flood-induced initiating-event frequency, this SR allows the possibility for mitigating features or human intervention to be part of the calculation, if applicable. Note that documenting the basis for nonapplicability requires that all SRs in HLR-IE-C in Part 2 are reviewed and dispositioned accordingly.
IFEV-B3	Generic pipe rupture data from industry sources can be used in deriving internal flood initiating-event frequencies. Examples of generic pipe rupture rates for use in estimating flood initiating-event frequencies may be found in the most recent EPRI report on "Pipe Rupture Frequencies for Internal Flooding Probabilistic Risk Assessments," [3-A-3], or the future superseding document. This generic data source is updated frequently. When accounting for any aging effects, ensure that the appropriate service time is considered for any new or replaced piping systems.
IFEV-B4	When estimating human-induced flood frequencies, the use of human reliability techniques in conjunction with maintenance frequencies is one method that can be used but is not an exclusive requirement to satisfy CC-II for this SR. Note that documenting the basis for nonapplicability requires that all SRs in HLR-HR-A, HLR-HR-B, HLR-HR-C, through HLR-HR-D in Part 2 are reviewed and dispositioned accordingly.
IFEV-B5	If screening of internal flood-induced initiating events is desired, then any of the listed screening criteria in this SR must be satisfied to invoke this option. Item *(b)* of this SR is an additional screening criterion unique to internal flood hazards and is an exception to the screening criteria listed in Table 1-1.8-1.
IFEV-B6	Reasonable alternatives are associated with the assumptions made in the Internal Flood Initiating Event Analysis.

Table 3-A.2.4-4 Commentary to Supporting Requirements for HLR-IFEV-C

Index No. IFEV-C	Commentary
IFEV-C1	An example method to demonstrate that this SR is satisfied is a cross-reference identifying each SR and where it is addressed in the documentation. This example of a documentation method facilitates PRA applications, upgrades, and peer reviews. Note that documenting the basis for nonapplicability requires that SR DA-E1, SR SY-C1, and SR IE-D1 in Part 2 are reviewed and dispositioned accordingly.
IFEV-C2	Source of model uncertainty is defined in Section 1-2.2.

3-A.2.5 COMMENTARY TO INTERNAL FLOOD PLANT RESPONSE ANALYSIS (IFPR)

In the Internal Flood PRA Plant Response Analysis technical element, accident sequences that may result from the internal flood initiating events and the corresponding system models are developed to represent the plant response to the flood scenarios and form the basis for Internal Flood Risk Quantification.

The Internal Flood PRA Plant Response Analysis should ensure the following:

(a) The plant response model is capable of determining flood-induced CDF and LERF and identifying the risk-significant contributors to the flood-induced risk.

(b) The equipment (e.g., structures, systems, components, instrumentation, barriers) is properly modeled and accounts for the appropriate flood-related failure impacts.

(c) The modeled equipment and HFEs represent the as-built, as-operated plant, considering the reactor type, design vintage, and specific design.

(d) The HFEs are properly modeled, including both non–flood-specific and flood-related actions.

(e) Findings associated with the internal-events analysis have been dispositioned such that they do not adversely impact the internal flood PRA.

Table 3-A.2.5-1 Commentary to High Level Requirements for Internal Flood Plant Response Analysis (IFPR)

Designator	Commentary
HLR-IFPR-A	The internal flood PRA plant response analysis model developed must be able to quantify CCDP, CLERP, CDF, and LERF. The model should also have sufficient level of detail to allow the determination of risk-significant contributors.
HLR-IFPR-B	No commentary provided.
HLR-IFPR-C	It is important to document the development of internal flood PRA plant response model in a manner that facilitates peer reviews and future updates/upgrades.

Table 3-A.2.5-2 Commentary to Supporting Requirements for HLR-IFPR-A

Index No. IFPR-A	Commentary
IFPR-A1	The internal flood PRA plant response model must be able to calculate CCDP and CLERP.
IFPR-A2	The internal flood PRA plant response model must be able to calculate CDF and LERF.
IFPR-A3	The internal flood PRA plant response model must include sufficient level of detail to facilitate the determination of risk-significant contributors.

Table 3-A.2.5-3 Commentary to Supporting Requirements for HLR-IFPR-B

Index No. IFPR-B	Commentary
IFPR-B1	No commentary provided.
IFPR-B2	The internal-events PRA plant response model is typically used as the starting point for the development of the internal flood PRA plant response model. All significant deficiencies found in the peer review and any other exceptions for the internal-events PRA should have been properly resolved, and the disposition of these issues should not adversely affect the development of the internal flood PRA plant response model. The definition of significant deficiency needs to be considered in the context of the regulatory framework (i.e., outside of this Standard and on a country-by-country basis). In the United States, the PRA peer review guidance indicates that a Finding-level observation impacts the technical adequacy of the PRA and, therefore, is a significant deficiency. Note that "significant" in this context is not to be strictly intended as risk significant.
IFPR-B3	This SR addresses the modification of the accident sequences for the same initiating events from the internal-events PRA to adequately model the plant response following the internal flood-induced initiating events. This SR is consistent with SR PRM-B5 in Part 4. Note that documenting the basis for nonapplicability requires that all SRs in HLR-AS-A and HLR-AS-B in Part 2 are reviewed and dispositioned accordingly.
IFPR-B4	This SR addresses the accident sequences for new initiating events identified for the internal flood PRA. This SR is consistent with SR PRM-B6 in Part 4. Note that documenting the basis for non-applicability requires that all SRs in HLR-AS-A and HLR-AS-B in Part 2 are reviewed and dispositioned accordingly.
IFPR-B5	This SR is consistent with SR PRM-B7 in Part 4. Note that documenting the basis for nonapplicability requires that all SRs in HLR-SC-A in Part 2 are reviewed and dispositioned accordingly.
IFPR-B6	This SR is consistent with SR PRM-B8 in Part 4. Note that documenting the basis for nonapplicability requires that all SRs in HLR-SC-B in Part 2 are reviewed and dispositioned accordingly.
IFPR-B7	This SR addresses the modification to the systems models and does not include any new data analysis that may be needed. The requirements for any new data analysis are included SR IFQU-A3. The equivalent SR in Part 4 is SR PRM-B9; however, SR PRM-B9 also addresses the requirements for any new data analysis. Note that documenting the basis for nonapplicability requires that all SRs in HLR-SY-A and HLR-SY-B in Part 2 are reviewed and dispositioned accordingly.
IFPR-B8	No commentary provided.
IFPR-B9	The new accident progression sequences addressed in this SR should include the effects of internal flood scenarios on system operability/functionality, operator actions, accident progression, and possible containment failures, including flooding damage to plant equipment. This SR is consistent with SR PRM-B14 in Part 4. Note that documenting the basis for nonapplicability requires that all SRs in HLR-LE-A, HLR-LE-B, HLR-LE-C, and HLR-LE-D in Part 2 are reviewed and dispositioned accordingly.
IFPR-B10	Note that documenting the basis for nonapplicability requires that all requirements in SR SC-A5 in Part 2 are reviewed and dispositioned accordingly.
IFPR-B11	Reasonable alternatives are associated with the assumptions made in the development of the internal flood PRA plant response analysis model. Source of model uncertainty is defined in Section 1-2.2.

Table 3-A.2.5-4 Commentary to Supporting Requirements for HLR-IFPR-C

Index No. IFPR-C	Commentary
IFPR-C1	This SR should address aspects of the internal flood PRA plant response model that have been modified or are otherwise unique in comparison to those in the internal-events PRA model. Documentation of aspects that have not been modified in the internal flood PRA are expected to be already documented in the internal-events notebooks. An example method to demonstrate that this SR is satisfied is a cross-reference identifying each SR and where it is addressed in the documentation. This example of a documentation method facilitates PRA applications, upgrades, and peer reviews. Additional examples of items that can be included in the documentation for internal flood plant response model development are *(a)* internal flood timelines and plant response strategies for those flood mechanisms analyzed in the internal flood PRA *(b)* internal flood event and fault trees *(c)* the specific adaptations made in the internal-events PRA model to produce the internal flood PRA model and the basis for those adaptations or a description of ad hoc models developed specifically for the internal flood PRA Note that documenting the basis for nonapplicability requires that all applicable SRs in Part 2 are reviewed and dispositioned accordingly.
IFPR-C2	Source of model uncertainty is defined in Section 1-2.2.

3-A.2.6 COMMENTARY TO INTERNAL FLOOD HUMAN RELIABILITY ANALYSIS (IFHR)

In the Internal Flood Human Reliability Analysis technical element, the HFEs are identified, and the associated HEPs are quantified, including dependencies among HFEs.

The Internal Flood Human Reliability Analysis should ensure the following:

(a) For a selected set of flood-induced scenarios, the corresponding HFEs were identified to determine their applicability.

(b) The reliability of operator actions in response to internal flood scenarios were included in the HEP quantification.

(c) Performance issues were included in the HEP quantifications to which they apply.

(d) The HRA was performed consistently with the applicable requirements in Part 2, and all scenario-specific impacts on performance shaping factors were included.

A selected review of walkdown(s) was conducted to confirm the feasibility of operator action to mitigate the internal flood.

Table 3-A.2.6-1 Commentary to High Level Requirements for Internal Flood Human Reliability Analysis (IFHR)

Designator	Commentary
HLR-IFHR-A	This HLR addresses the identification of applicable HFEs modeled in the internal-events PRA and new HFEs specific to the internal flood PRA.
HLR-IFHR-B	This HLR requires that those HFEs that can affect the response to internal flood initiating events be included in the internal flood PRA plant response model.
HLR-IFHR-C	This HLR requires the quantification of the HEPs for the HFEs identified and included in the internal flood PRA plant response model.
HLR-IFHR-D	This HLR addresses the recovery actions in the internal flood PRA and the identification of sources of model uncertainty and related assumptions associated with the Internal Flood Human Reliability Analysis.
HLR-IFHR-E	This HLR addresses the documentation requirements for the Internal Flood Human Reliability Analysis.

Table 3-A.2.6-2 Commentary to Supporting Requirements for HLR-IFHR-A

Index No. IFHR-A	Commentary
IFHR-A1	The following clarifications apply to this supporting SR: *(a)* Where SR HR-E1 in Part 2 specifies "in the context of the accident scenarios," include the effects resulting from the internal flood events. *(b)* Where SR HR-E1 in Part 2 specifies procedures, they are to include procedures for responding to conditions that can be caused by internal floods. Note that documenting the basis for nonapplicability requires that all SRs in HLR-HR-E in Part 2 are reviewed and dispositioned accordingly.
IFHR-A2	The requirements in SR IFHR-A1 address HFEs carried over from the internal-events analysis. SR IFHR-A2 addresses new HFEs that are unique to the internal flooding analysis. Operator actions evaluated for the internal flooding analysis need to take into account the unique timing and damage aspects of each internal flooding hazard (e.g., flooding, jet impingement, steam environment). The intent of the CC-I requirement in SR IFHR-A2 is that the internal flood PRA does not include the identification of any new, undesired operator actions (e.g., terminating a mitigation action), which could result from failures of indicators and annunciators caused by internal flood-induced failure mechanisms. If the analysis includes some identification of these undesired actions, then CC-I expects that the underlying methods and assumptions be described but without an implied judgment regarding adequacy or completeness. The following clarifications apply to this SR: *(a)* Where SR HR-E1 in Part 2 specifies "in the context of the accident scenarios," include the effects resulting from the internal flood events. *(b)* Where SR HR-E1 in Part 2 specifies procedures, they include procedures for responding to conditions that can be caused by internal floods. Note that documenting the basis for nonapplicability requires that all SRs in HLR-HR-E in Part 2 are reviewed and dispositioned accordingly.

Table 3-A.2.6-3 Commentary to Supporting Requirements for HLR-IFHR-B

Index No. IFHR-B	Commentary
IFHR-B1	HFEs related to actions previously modeled in an analysis such as the internal-events PRA may have to be modified because the internal flood may change the scenario characteristics such as timing, cues, or specific actions that would have to be taken (e.g., due to internal-flooded pathways that affect the operator action transit routes). These changes would therefore require alteration of a previously defined HFE to fit the applicable internal flood situation in the internal flood PRA.
IFHR-B2	Note that documenting the basis for nonapplicability requires that all SRs in HLR-HR-F in Part 2 are reviewed and dispositioned accordingly.
IFHR-B3	Considerations should include flood indication availability and expected time available for human response actions to be performed for the most challenging flood for the flood sources being addressed. Note that documenting the basis for nonapplicability requires that all SRs in HLR-HR-F in Part 2 are reviewed and dispositioned accordingly.

Table 3-A.2.6-4 Commentary to Supporting Requirements for HLR-IFHR-C

Index No. IFHR-C	Commentary
IFHR-C1	One acceptable method for meeting this requirement is stated in EPRI Guidelines on internal flooding PRA [3-A-1], including its definition of detailed analysis versus screening/scoping methods. Attention should be given to how the internal flood situation alters any previous assessments in non-internal-flood analyses relative to the influencing factors and the timing considerations addressed in SR HR-G3, SR HR-G4, SR HR-G5, and SR HR-G8 in Part 2 for Human Reliability Analysis. The HEPs may be increased for some hazard actions compared with the probabilities assigned in analogous internal-events initiated sequences. A typical hazard HRA aspect is consideration of the possibility that the hazard can cause damage or plant conditions that preclude personnel access to safety equipment or controls, thereby inhibiting human actions that might otherwise be credited. This information is most effectively collected during walkdowns, which must be structured to search for access issues. For all other HFEs determined not risk significant under CC-II, conservative estimates (e.g., screening values) or detailed analysis should be used. Note that documenting the basis for nonapplicability requires that all SRs in HLR-HR-G in Part 2 are reviewed and dispositioned accordingly.

Table 3-A.2.6-5 Commentary to Supporting Requirements for HLR-IFHR-D

Index No. IFHR-D	Commentary
IFHR-D1	Flood-specific operator recovery actions are those used to mitigate or recover flooding scenarios such as terminate or contain the flood propagation. They may include closing a valve to isolate a leak or shutting down pumps to terminate flow. The restoration of safety functions can be inhibited by any of several types of causes, including SSC damage or failure, access problems, confusion, loss of supporting personnel to other post-hazard recovery functions, and so on. Careful consideration of these causes must be given before recoveries are credited in the initial period after the occurrence of the hazard. Note that documenting the basis for nonapplicability requires that SR HR-H1, SR HR-H2, and SR HR-H3 in Part 2 are reviewed and dispositioned accordingly.
IFHR-D2	Reasonable alternatives are associated with the assumptions made in the Internal Flood Human Reliability Analysis.

Table A-3-2.6-6 Commentary to Supporting Requirements for HLR-IFHR-B

Index No. IFHR-E	Commentary
IFHR-E1	An example of one method to satisfy this SR is a cross-reference identifying each SR and where it is addressed in the documentation. This example of a documentation method facilitates PRA applications, upgrades, and peer reviews. The following are additional examples of items that can be included in the documentation of Internal Flood Human Reliability Analysis: *(a)* insights from talk-throughs, tabletop exercises, or simulations *(b)* those internal flood-related influences that affect methods, processes, or assumptions used as well as the identification and quantification of the HFEs in accordance with HLR-IFHR-A, HLR-IFHR-C, and HLR-IFHR-D *(c)* the recovery human actions included in the plant response model Note that documenting the basis for nonapplicability requires that all SRs in HLR-HR-I in Part 2 are reviewed and dispositioned accordingly.
IFHR-E2	Source of model uncertainty is defined in Section 1-2.2.

3-A.2.7 COMMENTARY TO INTERNAL FLOOD RISK QUANTIFICATION (IFQU)

In the Internal Flood Risk Quantification technical element, the CDF and LERF results for the internal flood plant response model sequences are quantified.

The internal flood accident sequence and quantification analysis should ensure the following:

(a) For a selected set of flood-induced scenarios, the corresponding sequences for the plant-initiating event are applicable.

(b) The flood-induced scenarios screened out at this level were identified, and the screening was performed appropriately.

(c) The flood accident sequences were quantified in accordance with the applicable SRs in Part 2, and the combined effects of flood-induced failures of SSCs were properly analyzed.

(d) For selected flood accident sequences, the contribution to CDF and LERF was evaluated correctly.

(e) A walkdown is required to confirm the accuracy of the information obtained from plant information sources to assess the appropriateness of HRA, spray or other impact assessment, and engineering analyses on the quantification results.

Table 3-A.2.7-1 Commentary to High Level Requirements for Internal Flood Risk Quantification (IFQU)

Designator	Commentary
HLR-IFQU-A	This HLR addresses the quantification of internal flood-induced CDF.
HLR-IFQU-B	This HLR addresses the requirements for the CDF quantification tools, process, and limitations.
HLR-IFQU-C	This HLR addresses the dependencies involved in the internal flood PRA quantification.
HLR-IFQU-D	This HLR addresses the quantification of internal flood-induced LERF.
HLR-IFQU-E	This HLR requires the identification of risk-significant contributors in the quantification of internal flood-induced CDF and LERF.
HLR-IFQU-F	This HLR requires the evaluation of impacts of model uncertainties and related assumptions on the CDF and LERF.
HLR-IFQU-G	This HLR addresses the documentation requirements for the quantification of the internal flood PRA.

Table 3-A.2.7-2 Commentary to Supporting Requirements for HLR-IFQU-A

Index No. IFQU-A	Commentary
IFQU-A1	The systems and accident sequence model for an internal flood PRA is commonly based on the internal-events, at-power PRA systems model, to which a number of items are added such as internal flood-induced initiating events as well other basic events (e.g., new or adjusted HEPs for the specific internal flood hazard). Internal-events accident sequence models may also be modified or some sequences not used for a given internal flood-induced initiating event. Screening out certain parts of the internal-events systems model from explicit incorporation in the internal flood PRA model is common (the screening can take the form of explicitly deleting the logic in the internal flood PRA or by bypassing or directly failing the logic, as appropriate). New system fault tree logic and/or accident sequence logic may need to be developed and added into the internal flood PRA model.
IFQU-A2	No commentary provided.
IFQU-A3	This SR includes any new data analysis to support the quantification of internal flood-induced accident sequences. SR IFPR-B7 addresses the modification to the systems models and does not include any new data analysis that may be needed. Note that documenting the basis for nonapplicability requires that all SRs in HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D in Part 2 are reviewed and dispositioned accordingly.
IFQU-A4	This SR requires that the analyst perform the appropriate assessments to confirm the correctness of the CDF calculation process as applied to the internal flood accident sequences. Note that documenting the basis for nonapplicability requires that all SRs in HLR-QU-A in Part 2 are reviewed and dispositioned accordingly.
IFQU-A5	No commentary provided.
IFQU-A6	Note that walkdown(s) may be performed in conjunction with SR IFPP-B4, SR IFSO-A7, and SR IFSN-A17. When determining the scope and details of the walkdown, it is important that the intent of the walkdown be considered. The intent is to identify items that invalidate modeling in the PRA to such an extent that the model does not reasonably represent the as-built, as-operated plant. In keeping with this intent, it is acceptable that conditions that can be justified as not likely to affect the results (i.e., will not change the risk profile or insights) do not need to be validated. As such, and per Inquiry 20-2435 [3-A-2], it is not required that 100% walkdown be performed if adequate justification can be provided that a lesser scope will suffice. Various justifications could be considered valid, but they must show that *(a)* items that could have a significant impact were walked down and *(b)* those items not walked down could not have a significant impact. The following are examples of possible justifications: *(a) Bounding Risk Impact*: If the importance measure of an item is low, such that even if the item was were assumed failed all the time, the PRA results would not meaningfully change. *(b) Adequacy of Documentation*: There is a sufficient weight of evidence, through drawings, photos/videos, analyses, or interviews with knowledgeable plant staff, that the conditions are as assumed in the PRA. *(c) Impact of Possible Discoveries*: Given past experience with the types of deviations typically found during walkdowns, it is not credible or likely that a deviation would be found that could affect the conditions assumed in the PRA to the extent required to meaningfully change the results.
IFQU-A7	The compilation of the assumptions and associated sources of model uncertainty from the internal flooding PRA for this SR generates the list of uncertainties that can be considered for the impact on the base internal flood PRA and in a specific application. Reasonable alternatives are associated with the assumptions made in the Internal Flood Risk Quantification. Note that documenting the basis for nonapplicability requires that all SRs in HLR-QU-E in Part 2 are reviewed and dispositioned accordingly.

Table 3-A.2.7-3 Commentary to Supporting Requirements for HLR-IFQU-B

Index No. IFQU-B	Commentary
IFQU-B1	Caution should be exercised when satisfying SR QU-B3 in Part 2, as the 5% truncation rule noted in that SR is only an example and is not intended to be a requirement. Note that documenting the basis for nonapplicability requires that all SRs in HLR-QU-B in Part 2 are reviewed and dispositioned accordingly.

Table 3-A.2.7-4 Commentary to Supporting Requirements for HLR-IFQU-C

Index No. IFQU-C	Commentary
IFQU-C1	Note that documenting the basis for nonapplicability requires that all SRs in HLR-QU-C in Part 2 are reviewed and dispositioned accordingly.

Table 3-A.2.7-5 Commentary to Supporting Requirements for HLR-IFQU-D

Index No. IFQU-D	Commentary
IFQU-D1	This SR requires that the analyst perform the appropriate assessments to confirm the correctness of the LERF model as applied to internal flood accident-progression sequences. Note that documenting the basis for nonapplicability requires that all requirements in HLR-LE-E in Part 2 are reviewed and dispositioned accordingly.
IFQU-D2	No commentary provided.

Table 3-A.2.7-6 Commentary to Supporting Requirements for HLR-IFQU-E

Index No. IFQU-E	Commentary
IFQU-E1	There is no requirement for a comparison of internal flood PRA results for similar plants under this SR, due to lack of publicly available internal flood PRA results. Additionally, differences in spatial factors, pipe routing, equipment location, flow paths, geometry, plant layout, and procedures may result in significant differences in risk that may be difficult to understand without detailed internal flood PRA results from plants being compared. Therefore, a direct comparison of the internal flood PRA results with other plants is not applicable. Note that documenting the basis for nonapplicability requires that all SRs in HLR-QU-D, SR LE-F1, and SR LE-F2 in Part 2 are reviewed and dispositioned accordingly.

Table 3-A.2.7-7 Commentary to Supporting Requirements for HLR-IFQU-F

Index No. IFQU-F	Commentary
IFQU-F1	The characterization of the assumptions and associated sources of model uncertainty provides an estimated change on the base internal flood PRA. An example method to satisfy this SR is to satisfy SR QU-E1 in Part 2 for the additional assumptions identified in SR IFPP-B5, SR IFSO-A8, SR IFSN-A18, SR IFEV-B6, SR IFPR-B11, SR IFHR-D2, and SR IFQU-A7.
IFQU-F2	In general, flood-induced accident sequences will comprise a combination of initiating events and basic events associated with *(a)* internal flood-induced initiating events *(b)* portions of the accident sequences derived from the internal-events PRA model (i.e., basic events that are independent of the flood scenarios but otherwise contribute to the accident sequence) Thus, the sources of model uncertainty that impact quantification include a combination of uncertainties associated with the flood scenarios and flood-induced initiating events plus those that are carried over from the internal-events PRA model. These requirements, namely, SR IFQU-F2, SR QU-E2, and SR LE-F3 in Part 2, include all sources of model uncertainty that impact the flood-induced accident sequence analysis. Note that documenting the basis for nonapplicability requires that all SRs in HLR-QU-E and SR LE-F3 in Part 2 are reviewed and dispositioned accordingly.

Table 3-A.2.7-8 Commentary to Supporting Requirements for HLR-IFQU-G

Index No. IFQU-G	Commentary
IFQU-G1	An example method to demonstrate that this SR is satisfied is a cross-reference identifying each SR and where it is addressed in the documentation. This example of a documentation method facilitates PRA applications, upgrades, and peer reviews. Satisfy the CC-I or CC-II requirements in HLR-QU-F for quantification, HLR-LE-G for LERF Analysis, and HLR-DA-E for Data Analysis in Part 2 except where the requirements are not applicable, with the following clarifications: *(a)* SR QU-F2 and SR QU-F3 in Part 2 are to be met, including identification of which internal flood scenarios and which flood areas (consistent with the level of resolution of the internal flood PRA such as internal flood areas) are risk-significant contributors. *(b)* SR DA-E2 in Part 2 is to be met consistently with SR IFQU-A3. *(c)* SR LE-G2 in Part 2 is to be met consistently with SR IFQU-D1 and SR IFQU-D2. *(d)* SR QU-F4 and SR LE-G4 in Part 2 are to be met consistently with SR IFQU-F2. Note that documenting the basis for nonapplicability requires that SR QU-F1, SR QU-F2, SR LE-G1, SR LE-G2, SR DA-E1, and SR DA-E2 in Part 2 are reviewed and dispositioned accordingly.
IFQU-G2	No commentary provided.
IFQU-G3	Source of model uncertainty is defined in Section 1-2.2.
IFQU-G4	No commentary provided.

3-A.3 REFERENCES

The following is a list of publications referenced in this Appendix.

[3-A-1] EPRI Report 1019194, "Guidelines for Performance of Internal Flooding Probabilistic Risk Assessment," 2009 (including the update and erratum dated August 5, 2020); Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA, 94304-1388

[3-A-2] JCNRM Inquiry Record 20-2435, The American Society of Mechanical Engineers (ASME) and the American Nuclear Society (ANS), Joint Committee Nuclear Risk Management (JCNRM) Inquiries and Interpretations, ASME, https://cstools.asme.org/csconnect/CommitteePages.cfm?Committee=100186782&Action=40886

[3-A-3] EPRI Report 3002000079, Rev. 3, "Pipe Rupture Frequencies for Internal Flooding Probabilistic Risk Assessments," 2013; Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA, 94304-1388

PART 4
REQUIREMENTS FOR INTERNAL FIRES AT-POWER PRA

Section 4-1
Risk Assessment Technical Requirements for Internal Fires At-Power

4-1.1 PRA SCOPE

This Part states technical requirements for a Level 1 and large early release frequency (LERF) analysis of internal fires while at-power. Note that the term “internal fire” as used in this Standard is defined as any fire originating within the global analysis boundary as defined per the Internal Fire Plant Boundary Definition and Partitioning Plant Partitioning technical element (see Section 4-2.1).

4-1.2 COORDINATION WITH OTHER PARTS OF THIS STANDARD

This Part is intended to be used together with Part 1 and Part 2 of this Standard. An internal-events at-power PRA developed in accordance with Part 2 is the starting point for the development of the internal fire PRA model. The internal fire PRA may produce or be accompanied by other hazards, such as seismic-induced fire, and so also coordinates with Part 5 and Part 9.

(The text presented in **blue font** in this Standard comprise hyperlinks to enable efficient access to referenced sections and elements, requirements, notes, references, etc.)

Section 4-2
Internal Fire PRA Technical Elements and Requirements

The requirements of this Part are organized into the following 10 technical elements:

(a) Internal Fire Plant Boundary Definition and Partitioning (PP)
(b) Internal Fire Initiating Events and Equipment Selection (ES)
(c) Internal Fire Cable Selection and Location (CS)
(d) Internal Fire Qualitative Screening (QLS)
(e) Internal Fire Plant Response Model (PRM)
(f) Internal Fire Scenario Selection and Analysis (FSS)
(g) Internal Fire Ignition Frequency (IGN)
(h) Internal Fire Circuit Failure Analysis (CF)
(i) Internal Fire Human Reliability Analysis (FHR)
(j) Internal Fire Risk Quantification (FQ)

4-2.1 INTERNAL FIRE PLANT BOUNDARY DEFINITION AND PARTITIONING (PP)

4-2.1.1 Objectives

The objectives of the Internal Fire Plant Boundary Definition and Partitioning technical element are to define

(a) the global analysis boundary of the internal fire PRA, that is, to define the physical extent of the plant to be encompassed by the internal fire analysis

(b) the physical analysis units (PAUs) on which the analysis will be based

Fire PRA is driven largely by spatial considerations; thus, the basic internal fire PRA PAUs are defined in terms of physical regions (or volumes) of the plant.

The Supporting Requirements (SRs) for the Internal Fire Plant Boundary Definition and Partitioning technical element make no distinctions based on Capability Category. The purpose of the Internal Fire Plant Boundary Definition and Partitioning technical element is not to delineate capability categories distinctions; rather, it is to ensure that the internal fire PRA clearly defines the extent of the analysis (i.e., the global analysis boundary) and a set of spatial locations that will form the primary basis for organization of the analysis (i.e., the PAUs). The primary intent of the Internal Fire Plant Boundary Definition and Partitioning requirements is to ensure that the boundaries that define each PAU will substantially contain the damaging fire behaviors. In general terms, "substantially contain damaging fire behaviors" is interpreted in the context of fire-plume development, the development of a hot gas layer, direct radiant heating by the fire, and the actual spread of fire between contiguous or noncontiguous combustibles. Smoke-spread behavior is not a required consideration in the partitioning analysis (any potential for damage due to smoke spread beyond a fire compartment is included in the multicompartment fire scenarios; see HLR-FSS-G and its corresponding SRs).

Table 4-2.1-1 High Level Requirements for Internal Fire Plant Boundary Definition and Partitioning (PP)

Designator	Requirement
HLR-PP-A	The internal fire PRA shall define the global analysis boundary to include all plant locations relevant to the plantwide fire PRA.
HLR-PP-B	The internal fire PRA shall perform a plant partitioning analysis to identify and define the PAUs to be evaluated in the fire PRA.
HLR-PP-C	The documentation of the Internal Fire Plant Boundary Definition and Partitioning shall provide traceability of the work.

Table 4-2.1-2 Supporting Requirements for HLR-PP-A

The internal fire PRA shall define the global analysis boundary to include all plant locations relevant to the plantwide fire PRA (HLR-PP-A).

Index No. PP-A	Capability Category I	Capability Category II
PP-A1	INCLUDE within the global analysis boundary all fire areas, fire compartments, or locations within the licensee-controlled area where a fire could adversely affect any equipment or cable item to be included in the plant response model for internal fire.	

Table 4-2.1-3 Supporting Requirements for HLR-PP-B

The internal fire PRA shall perform a plant partitioning analysis to identify and define the PAUs to be evaluated in the internal fire PRA (HLR-PP-B).

Index No. PP-B	Capability Category I	Capability Category II
PP-B1	DEFINE a set of fire PRA PAUs that represent the physical characteristics of the plant, the nature of the fire hazards present in each plant location, and the potential extent of fire damage that could reasonably result from fires involving those fire sources.	
PP-B2	If any physical plant feature that lacks a specific fire-endurance rating has been credited as a partitioning element in defining the boundaries of the PAUs (see SR PP-B1), JUSTIFY the judgment that the nonrated partitioning element will substantially contain the damaging effects of fires, given the nature of the fire sources present in each PAU, separated by the nonrated partitioning element.	
PP-B3	DO NOT CREDIT raceway fire barriers, thermal wraps, fire-retardant coatings, radiant energy shields, or any other localized cable or equipment protection feature as partitioning elements in defining PAUs.	
PP-B4	ENSURE *(a)* that, collectively, the defined PAUs encompass all locations within the global analysis boundary (see SR PP-A1) *(b)* that defined PAUs do not overlap	
PP-B5	COLLECT information on credited barriers that are not maintained as a part of the fire-protection program to confirm the conditions and characteristics of credited partitioning elements via a confirmatory walkdown.	
PP-B6	JUSTIFY the exclusion of any locations within the licensee-controlled area from the global analysis boundary by demonstrating that they do not satisfy the selection criteria as defined per SR PP-A1.	
PP-B7	IDENTIFY the sources of model uncertainty and assumptions associated with the plant partitioning analysis (HLR-PP-A, HLR-PP-B).	

Table 4-2.1-4 Supporting Requirements for HLR-PP-C

The documentation of the Internal Fire Plant Boundary Definition and Partitioning shall provide traceability of the work (HLR-PP-C).

Index No. PP-C	Capability Category I	Capability Category II
PP-C1	DOCUMENT the process used in the Internal Fire Plant Boundary Definition and Partitioning specifying the inputs to the Internal Fire Plant Boundary Definition and Partitioning technical element, the applied methods, and the results. The documentation includes, as a minimum, *(a)* the approach used for developing the plant partitioning analysis *(b)* identification of plant documentation used in support of the Internal Fire Plant Boundary Definition and Partitioning technical element *(c)* the exclusion of any locations within the licensee-controlled area that are not included in the global analysis boundary *(d)* the general nature and key or unique features of the partitioning elements that define each PAU defined in plant partitioning *(e)* the internal fire PRA PAUs *(f)* the walkdown process *(g)* the results of the plant partitioning	
PP-C2	DOCUMENT the sources of model uncertainty and assumptions associated with the Internal Fire Plant Boundary Definition and Partitioning (HLR-PP-A, HLR-PP-B).	

4-2.2 INTERNAL FIRE INITIATING EVENTS AND EQUIPMENT SELECTION (ES)

The objective of Internal Fire Initiating Events and Equipment Selection is to identify the initiating events and the plant equipment that will be included in the plant response model for internal fire.

Note that the identification of initiating events and fire PRA equipment serves as the foundation for identifying corresponding cables that will need to be selected and located under the Internal Fire Cable Selection and Location technical element (nonelectrical equipment will not need cable information but may still be in the internal fire PRA).

The requirements in the Internal Fire Initiating Events and Equipment Selection technical element cite distinctions between two broad classes of fire-induced equipment failures: loss of function failures and spurious operation failures. Loss of function failures are the more traditional mode of equipment failure widely treated in PRAs, including failure to start, failure to run, failures of active equipment, and failures of instrument and indication circuits potentially causing loss of signals. Spurious operation failures are unique to fire PRA and involve the activation of equipment or the development of erroneous indications resulting from fire-induced cable/circuit failures. The requirements for treatment of each class of failure are unique.

The requirements of the Internal Fire Initiating Events and Equipment Selection technical element complement the Internal Fire Plant Response Model technical element in which the plant response model for internal fire is developed. The requirements are written in anticipation that analysts will not be performing this technical element in a vacuum but will instead begin with a list of initiating events and equipment included in the internal-events plant response model.

Table 4-2.2-1 High Level Requirements for Internal Fire Initiating Events and Equipment Selection (ES)

Designator	Requirement
HLR-ES-A	The internal fire PRA shall identify fire-induced initiating events to be evaluated in the plant response model for internal fire and the equipment whose failure, including spurious operation, would cause each initiating event.
HLR-ES-B	The internal fire PRA shall identify equipment whose failure, including spurious operation, would compromise mitigating systems that are included in the internal fire PRA.
HLR-ES-C	The internal fire PRA shall identify instrumentation whose failure, including spurious operation, would impact the reliability of operator actions associated with that portion of the plant design to be included in the internal fire PRA.
HLR-ES-D	The documentation of the Internal Fire Initiating Events and Equipment Selection shall provide traceability of the work.

Table 4-2.2-2 Supporting Requirements for HLR-ES-A

The internal fire PRA shall identify the fire-induced initiating events to be evaluated in the plant response model for internal fire and the equipment whose failure, including spurious operation, could cause each initiating event (HLR-ES-A).

Index No. ES-A	Capability Category I	Capability Category II
ES-A1	For each initiating event included in the internal-events plant response model, and for each initiating event that was considered but screened out from the internal-events plant response model, either INCLUDE the initiating event in the plant response model for internal fire or JUSTIFY exclusion of the initiating event from the fire PRA plant response model.	
ES-A2	IDENTIFY the equipment whose internal fire-induced loss of function failure would cause any of the initiating events that have been included per SR ES-A1.	
ES-A3	IDENTIFY, by using a structured systematic process that meets the criteria set forth in SRs ES-A4, ES-A5, and ES-A6, any unique initiating events, and the equipment whose fire-induced failure including spurious operation would cause them, which are not already included per SRs ES-A1 and ES-A2.	
ES-A4	IDENTIFY equipment based on the consideration of cases where any single internal fire-induced spurious operation of equipment alone would cause an initiating event.	
ES-A5	IDENTIFY equipment based on the consideration of any single fire-induced spurious operations that, in combination with other fire-induced loss of function failures, would cause an initiating event.	IDENTIFY equipment based on the consideration of any single fire-induced spurious operations that, in combination with other fire-induced loss of function failures, would cause an initiating event. IDENTIFY equipment based on the consideration of combinations of two fire-induced spurious operations that, alone or in combination with other fire-induced loss of function failures, would cause an initiating event and *(a)* affect the portion of the plant design to be credited in response to the initiating event in the internal fire PRA or *(b)* result in a loss of reactor coolant system integrity
ES-A6	IDENTIFY equipment based on the consideration of up to two fire-induced spurious operations of equipment, alone or in combination with other fire-induced loss of function failures, that cause an initiating event and containment bypass.	IDENTIFY equipment based on the consideration of up to three fire-induced spurious operations of equipment, alone or in combination with other fire-induced loss of function failures, that cause an initiating event and containment bypass.
ES-A7	For any identified equipment from SRs ES-A3, ES-A4, ES-A5, and ES-A6, either INCLUDE the identified equipment in the plant response model for internal fire or JUSTIFY exclusion of equipment per the screening criteria SCR-2 or SCR-3 in Table 1-1.8-1.	

Table 4-2.2-3 Supporting Requirements for HLR-ES-B

The internal fire PRA shall identify equipment whose failure, including spurious operation, would compromise mitigating systems that are included in the internal fire PRA (HLR-ES-B).

Index No. ES-B	Capability Category I	Capability Category II
ES-B1	IDENTIFY plant equipment that is both vulnerable to fire-induced failure and whose failure could compromise mitigating systems modeled in the fire PRA.	
ES-B2	For every train of equipment that is included in the plant response model for internal fire, IDENTIFY equipment using a structured systematic process whose fire-induced failures, including any single spurious operation, will contribute to failure to meet the Success Criteria in the internal fire PRA.	For every train of equipment that is included in the plant response model for internal fire, IDENTIFY equipment using a structured systematic process whose fire-induced failures, up to and including two spurious operations, will contribute to failure to meet the Success Criteria in the internal fire PRA.
ES-B3	For any identified equipment from SRs ES-B1 and ES-B2, either INCLUDE the identified equipment in the plant response model for internal fire or JUSTIFY exclusion of equipment per the screening criteria SCR-3 in Table 1-1.8-1.	

Table 4-2.2-4 Supporting Requirements for HLR-ES-C

The internal fire PRA shall identify instrumentation whose failure, including spurious operation, would impact the reliability of operator actions associated with that portion of the plant design to be included in the internal fire PRA (HLR-ES-C).

Index No. ES-C	Capability Category I	Capability Category II
ES-C1	IDENTIFY instrumentation for which fire-induced failure is relevant in assessing the human failure events (HFEs) that are defined or modified to account for the context of fire scenarios in the internal fire PRA, per SRs FHR-B1 and FHR-B2.	IDENTIFY instrumentation for which fire-induced failure is relevant in assessing the HFEs that are defined or modified to account for the context of fire scenarios in the internal fire PRA, per SRs FHR-B1 and FHR-B2, including consideration of *(a)* loss of function *(b)* loss of signal failures *(c)* any fire-induced spurious/erroneous indications of a single instrument that would directly lead the operators to take an undesirable action impacting one or more of the safety functions modeled in the fire PRA
ES-C2	IDENTIFY the sources of model uncertainty and assumptions associated with the Internal Fire Initiating Events and Equipment Selection (HLR-ES-A, HLR-ES-B, and SR ES-C1).	

Table 4-2.2-5 Supporting Requirements for HLR-ES-D

The documentation of the Internal Fire Initiating Events and Equipment Selection shall provide traceability of the work (HLR-ES-D).

Index No. ES-D	Capability Category I	Capability Category II
ES-D1	DOCUMENT the process used in the Internal Fire Initiating Events and Equipment Selection specifying the inputs to the Internal Fire Initiating Events and Equipment Selection technical element, the applied methods, and the results. The documentation includes, as a minimum, *(a)* identification of the equipment associated with determining initiating events in the plant response model for internal fire for the postulated fires *(b)* the equipment and failures modes including spurious operation or indication to be included in the plant response model for internal fire.	
ES-D2	DOCUMENT the sources of model uncertainty and assumptions associated with the Internal Fire Initiating Events and Equipment Selection (HLR-ES-A, HLR-ES-B, HLR-ES-C).	

4-2.3 INTERNAL FIRE CABLE SELECTION AND LOCATION (CS)

The objectives of Internal Fire Cable Selection and Location is to ensure that

(a) cables needed to support proper operation of equipment identified per the Internal Fire Initiating Events and Equipment Selection technical element (see Section 4-2.2) are identified and assessed for relevance to the plant response model for internal fire

(b) the plant location information for the identified cables is sufficient to support the internal fire PRA and its intended applications

The level of spatial resolution for the cable location data has a direct effect on the precision of the resulting risk assessment. An important attribute of an internal fire PRA is the ability to correlate cable spatial location information to PAUs, to specific locations within a PAU, and/or to specific raceways, as applicable, to allow the analysis of fire consequences for the fire scenario under consideration.

Table 4-2.3-1 High Level Requirement for Internal Fire Cable Selection and Location (CS)

Designator	Requirement
HLR-CS-A	The internal fire PRA shall identify and locate the plant cables whose failure would adversely affect equipment or functions included in the fire PRA plant response model, as determined by the equipment selection process per HLR-ES-A, HLR-ES-B, and HLR-ES-C.
HLR-CS-B	The internal fire PRA shall perform a review for additional circuits associated with overcurrent protection that are required to support equipment included in the plant response model for internal fire (i.e., per HLR-CS-A).
HLR-CS-C	The documentation of the Internal Fire Cable Selection and Location shall provide traceability of the work.

Table 4-2.3-2 Supporting Requirements for HLR-CS-A

The internal fire PRA shall identify and locate the plant cables whose failure would adversely affect equipment or functions included in the plant response model for internal fire, as determined by the equipment selection process per HLR-ES-A, HLR-ES-B, and HLR-ES-C (HLR-CS-A).

Index No. CS-A	Capability Category I	Capability Category II
CS-A1	IDENTIFY, by using a structured and systematic process, cables whose fire-induced failure adversely affects equipment selected per the Internal Fire Initiating Events and Equipment Selection technical element and/or functions included in the plant response model for internal fire, with the exception of equipment excluded per SR CS-A2.	IDENTIFY, by using a structured and systematic process, cables whose fire-induced failure adversely affects equipment selected per the Internal Fire Initiating Events and Equipment Selection technical element and/or functions included in the plant response model for internal fire, with the exception of equipment excluded per SR CS-A2 and for equipment that is a risk-significant contributor, ASSOCIATE cables with equipment failure modes specific to each cable.
CS-A2	IDENTIFY systems and/or equipment selected per the requirements of the Internal Fire Initiating Events and Equipment Selection technical element for which cable selection and routing has not been performed, and JUSTIFY that the lack of cable selection and routing does not impact the insights associated with risk-significant contributors.	
CS-A3	For each PAU, IDENTIFY each cable, including its terminal locations, associated with a function included in the internal fire PRA that passes through the PAU.	For each PAU, IDENTIFY each cable, including its terminal locations, associated with a function (i.e., failure mode or basic event) included in the internal fire PRA that passes through the PAU and for fire scenarios that are risk-significant contributors, IDENTIFY the electrical raceways though which each target cable is routed.
CS-A4	If assumed cable routing is used in the internal fire PRA, SPECIFY the scope, extent, and basis.	

Table 4-2.3-3 Supporting Requirements for HLR-CS-B

The internal fire PRA shall perform a review for additional circuits associated with overcurrent protection that are required to support equipment included in the plant response model for internal fire (i.e., per HLR-CS-A) (HLR-CS-B).

Index No. CS-B	Capability Category I	Capability Category II
CS-B1	ASSESS the adequacy of the electrical overcurrent protective device coordination for distribution buses included in the plant response model for internal fire.	
CS-B2	IDENTIFY any additional circuits/cables whose fire-induced failure would challenge power supply availability due to inadequate overcurrent protective device coordination.	

Table 4-2.3-4 Supporting Requirements for HLR-CS-C

The documentation of the Internal Fire Cable Selection and Location shall provide traceability of the work (HLR-CS-C).

Index No. CS-C	Capability Category I	Capability Category II
CS-C1	DOCUMENT the process used in the Internal Fire Cable and Location specifying the inputs to the Internal Fire Cable Selection and Location technical elements, the applied methods, and the results. The documentation includes, as a minimum, *(a)* the cable selection and location results such that those results are traceable to plant source documents *(b)* the assumed cable routing and the basis for concluding that the routing is reasonable if the provision of SR CS-A4 is used *(c)* the review of the electrical distribution system overcurrent coordination and protection analysis	

4-2.4 INTERNAL FIRE QUALITATIVE SCREENING (QLS)

The objective of Internal Fire Qualitative Screening is to identify PAUs, consistent with the results of the Internal Fire Plant Boundary Definition and Partitioning analysis as discussed per HLR-PP-B and its SRs as specified in Section 4-2.1, whose potential fire-risk contribution can be shown to be negligible without quantitative analysis. In the Internal Fire Qualitative Screening technical element, PAUs are examined only in the context of their individual contribution to fire risk. The potential risk contribution of all PAUs is reexamined in the multicompartment fire scenario analysis regardless of the PAU's disposition during qualitative screening. See Section 4-2.6 for further discussion of the identification and evaluation of multicompartment fire scenarios.

The Internal Fire Qualitative Screening technical element is optional in an internal fire PRA. Under some circumstances, an analyst may choose to bypass the Internal Fire Qualitative Screening technical element and simply retain all PAUs for quantitative analysis. However, if any one (or more) PAU(s) defined as within the global analysis boundary is (are) not analyzed quantitatively, then a qualitative screening analysis is implied, and the Internal Fire Qualitative Screening technical element requirements would apply.

The SRs for Internal Fire Qualitative Screening are nominally the same for all capability categories. Qualitative screening identifies non-risk-contributing PAUs as individual contributors and independent of any other aspects of fire PRA resolution.

Table 4-2.4-1 High Level Requirement for Internal Fire Qualitative Screening (QLS)

Designator	Requirement
HLR-QLS-A	The internal fire PRA shall identify those PAUs that screen out as individual risk contributors without quantitative analysis.
HLR-QLS-B	The documentation of the Internal Fire Qualitative Screening shall provide traceability of the work.

Table 4-2.4-2 Supporting Requirements for HLR-QLS-A

The internal fire PRA shall identify those PAUs that screen out as individual risk contributors without quantitative analysis (HLR-QLS-A).

Index No. QLS-A	Capability Category I	Capability Category II
QLS-A1	RETAIN for quantitative analysis those PAUs that contain equipment or cables required to ensure as-designed circuit operation or whose failure could cause spurious operation of any equipment, system, function, or operator action included in the plant response model for internal fire per screening criteria in SCR-3 from Table 1-1.8-1.	
QLS-A2	RETAIN for quantitative analysis those PAUs where a fire might require a manual or automatic plant trip or a controlled shutdown based on plant Technical Specifications per screening criteria in SCR-3 from Table 1-1.8-1. If a time limit is established for a Technical Specification–required shutdown, SPECIFY the basis for the applied time window.	
QLS-A3	USE the screening criteria as defined by SRs QLS-A1 and QLS-A2 to each PAU defined in the Internal Fire Plant Boundary Definition and Partitioning technical element.	
QLS-A4	If additional qualitative screening criteria are applied, SPECIFY the applied criteria and the basis that demonstrates the applied criteria provide reasonable assurance that the screened-out PAUs are negligible contributors to internal fire risk in a manner consistent, at a minimum, with SRs QLS-A1, QLS-A2, and QLS-A3.	
QLS-A5	IDENTIFY the sources of model uncertainty and assumptions associated with the Internal Fire Qualitative Screening (HLR-QLS-A).	

Table 4-2.4-3 Supporting Requirements for HLR-QLS-B

The documentation of the Internal Fire Qualitative Screening shall provide traceability of the work (HLR-QLS-B).

Index No. QLS-B	Capability Category I	Capability Category II
QLS-B1	DOCUMENT the process used in the qualitative screening specifying the inputs to the Internal Fire Qualitative Screening technical element, the applied methods and the results. The documentation includes, as a minimum, *(a)* the qualitative screening criteria applied *(b)* the disposition of each PAU defined by the Internal Fire Plant Boundary Definition and Partitioning analysis as either "screened out" or "retained for quantitative analysis" *(c)* the basis for exclusion of each PAU defined in the Internal Fire Plant Boundary Definition and Partitioning analysis that has been screened out	
QLS-B2	DOCUMENT the sources of model uncertainty and assumptions associated with the Internal Fire Qualitative Screening analysis (HLR-QLS-A).	

4-2.5 INTERNAL FIRE PLANT RESPONSE MODEL (PRM)

The objective of Internal Fire Plant Response Model is to provide the basis for the identification of accident scenarios (accident sequences and accident sequence cutsets) introduced by internal fires.

The Internal Fire Plant Response Model requirements are written in anticipation that analysts will not be performing this technical element in a vacuum but will instead start with an internal-events PRA plant response model that has been assessed against Part 2 of this Standard. Many of the requirements in this Part call upon or otherwise parallel requirements found in Part 2 with clarifications as noted herein to produce the Internal Fire Plant Response Model.

The plant response model for internal fire includes modeling of the equipment failure modes attributable to fire-induced damage to either or both the equipment and cables depending on the location of the fire.

It is anticipated that substantial changes may be needed to the internal-events PRA model (i.e., the accident sequences) to meet the needs of the internal fire PRA. It is expected that the plant response model for internal fire will be constructed by modifying the corresponding internal-events PRA models, and the Internal Fire Plant Response Model requirements are written from this perspective. Elements of the plant response model for internal fire that are carried over directly from the internal-events PRA are assumed to meet the same Capability Category as assigned for the internal-events PRA unless that factor requires modification or reanalysis given the specific context of a fire event. In such cases, the assessment of the Capability Category met by the internal fire PRA may be unique.

Table 4-2.5-1 High Level Requirement for Internal Fire Plant Response Model (PRM)

Designator	Requirement
HLR-PRM-A	The internal fire PRA shall include the plant response model for internal fire capable of supporting HLR-FQ-A, HLR-FQ-B, HLR-FQ-C, HLR-FQ-D, HLR-FQ-E, and HLR-FQ-F.
HLR-PRM-B	The plant response model for internal fire shall include initiating events induced by internal fires, both fire-induced and random failures of equipment, fire-specific as well as non-fire-related human failures associated with safe shutdown, events in the accident progression sequences (e.g., containment failure modes), and the supporting probability data (including uncertainty) based on the SRs stated under this HLR that parallel, as appropriate, Part 2 of this Standard, for internal-events PRA.
HLR-PRM-C	The documentation of the Internal Fire Plant Response Model shall provide traceability of the work.

Table 4-2.5-2 Supporting Requirements for HLR-PRM-A

The internal fire PRA shall include the plant response model for internal fire capable of supporting HLR-FQ-A, HLR-FQ-B, HLR-FQ-C, HLR-FQ-D, HLR-FQ-E, and HLR-FQ-F (HLR-PRM-A).

Index No. PRM-A	Capability Category I	Capability Category II
PRM-A1	CONSTRUCT the plant response model for internal fire so that it is capable of determining conditional core damage probabilities and conditional large early release probabilities for the fire scenarios and their associated damage target sets, defined per the requirements of the Internal Fire Scenario Selection and Analysis technical element (see Section 4-2.6).	
PRM-A2	CONSTRUCT the plant response model for internal fire so that it is capable of determining core damage frequencies (CDFs) and LERFs once the fire frequencies (see HLR-IGN-A and HLR-IGN-B, Section 4-2.7) are also applied to the quantification.	
PRM-A3	CONSTRUCT the plant response model for internal fire model so that it is capable of determining the risk-significant contributors to the internal fire-induced risk, consistent with the Internal Fire Risk Quantification technical element (see Section 4-2.10).	

Table 4-2.5-3 Supporting Requirements for HLR-PRM-B

The plant response model for internal fire shall include initiating events induced by internal fires, both fire-induced and random failures of equipment, fire-specific as well as non-fire-related human failures associated with safe shutdown, events in the accident progression sequences (e.g., containment failure modes), and the supporting probability data (including uncertainty) based on the SRs stated under this HLR that parallel, as appropriate, Part 2 for internal-events PRA (HLR-PRM-B).

Index No. PRM-B	Capability Category I	Capability Category II
PRM-B1	USE the internal-events PRA initiating events and accident sequences for both CDF and LERF as the basis for development of the plant response model for internal fire.	
PRM-B2	ENSURE that significant deficiencies identified during the peer review for the internal-events and other-hazard PRAs that are relevant to the internal fire PRA are resolved and incorporated into the development of the Internal Fire Plant Response Model and that the disposition does not adversely affect the development of the plant response model for internal fire.	
PRM-B3	CONSTRUCT the plant response model for internal fire in a manner that includes cable damage effects on the equipment of interest per the requirements of the Internal Fire Initiating Events and Equipment Selection and Internal Fire Cable Selection and Location technical elements (see Sections 4-2.2 and 4-2.3).	
PRM-B4	For any new initiating events identified per SR ES-A3, SATISFY the Capability Category I (CC-I) requirements in HLR-IE-B in Part 2 for the Initiating Event Analysis except where the requirements are not applicable (e.g., excluding initiating events that cannot be induced by a fire).	For any new initiating events identified per SR ES-A3, SATISFY the Capability Category II (CC-II) requirements in HLR-IE-B in Part 2 for the Initiating Event Analysis except where the requirements are not applicable (e.g., excluding initiating events that cannot be induced by a fire).
PRM-B5	For those fire-induced initiating events included in the internal-events PRA plant-response model, review the corresponding accident sequence models and IDENTIFY *(a)* any existing accident sequences that will require modification based on unique aspects of the plant fire response procedures *(b)* any new accident sequences that might result from a fire event that were not included in the internal-events PRA and SATISFY the CC-I requirements in HLR-AS-A in Part 2 and HLR-AS-B in Part 2 for the Accident Sequence Analysis except where the requirements are not applicable.	For those fire-induced initiating events included in the internal-events PRA plant-response model, review the corresponding accident sequence models and IDENTIFY *(a)* any existing accident sequences that will require modification based on unique aspects of the plant fire response procedures and *(b)* any new accident sequences that might result from a fire event that were not included in the internal-events PRA and SATISFY the CC-II requirements in HLR-AS-A in Part 2 and HLR-AS-B in Part 2 for the Accident Sequence Analysis except where the requirements are not applicable.
PRM-B6	MODEL accident sequences for any new initiating events identified per SR ES-A3 and any accident sequences identified per SR PRM-B5 that represent possible plant responses to the fire-induced initiating events and SATISFY the CC-I requirements in HLR-AS-A in Part 2 and HLR-AS-B in Part 2 for the Accident Sequence Analysis except where the requirements are not applicable with the following clarifications: *(a)* All the SRs in HLR-AS-A and HLR-AS-B in Part 2 are to be addressed in the context of fire scenarios. *(b)* When applying SR AS-A5 in Part 2 to fire PRA, INCLUDE fire response procedures as well as emergency operating procedures and abnormal procedures.	MODEL accident sequences for any new initiating events identified per SR ES-A3 and any accident sequences identified per SR PRM-B5 that represent possible plant responses to the fire-induced initiating events and SATISFY the CC-II requirements in HLR-AS-A and HLR-AS-B in Part 2 for the Accident Sequence Analysis except where the requirements are not applicable with the following clarifications: *(a)* All the SRs in HLR-AS-A and HLR-AS-B in Part 2 are to be addressed in the context of fire scenarios. *(b)* When applying SR AS-A5 in Part 2 to fire PRA, INCLUDE fire response procedures as well as emergency operating procedures and abnormal procedures.

Table 4-2.5-3 Supporting Requirements for HLR-PRM-B (Cont'd)

The plant response model for internal fire shall include initiating events induced by internal fires, both fire-induced and random failures of equipment, fire-specific as well as non-fire-related human failures associated with safe shutdown, events in the accident progression sequences (e.g., containment failure modes), and the supporting probability data (including uncertainty) based on the SRs stated under this HLR that parallel, as appropriate, Part 2 for internal-events PRA (HLR-PRM-B).

Index No. PRM-B	Capability Category I	Capability Category II
PRM-B7	IDENTIFY any cases where new or modified Success Criteria will be needed to support the fire PRA and SATISFY the CC-I requirements in HLR-SC-A in Part 2 for Success Criteria except where the requirements are not applicable.	IDENTIFY any cases where new or modified Success Criteria will be needed to support the fire PRA and SATISFY the CC-II requirements in HLR-SC-A in Part 2 for Success Criteria except where the requirements are not applicable.
PRM-B8	DEFINE any new or modified Success Criteria identified per SR PRM-B7 and SATISFY the CC-I requirements in HLR-SC-B in Part 2 for Success Criteria except where the requirements are not applicable.	DEFINE any new or modified Success Criteria identified per SR PRM-B7 and SATISFY the CC-II requirements in HLR-SC-B in Part 2 for Success Criteria except where the requirements are not applicable.
PRM-B9	For any cases where new system models or split fractions are needed or existing models or split fractions need to be modified, INCLUDE in the plant response model for internal fire the effects of *(a)* fire-induced equipment failures *(b)* fire-specific operator actions as identified per the requirements of the Internal Fire Human Reliability Analysis technical element *(c)* fire-induced spurious operations as identified per the requirements of the Internal Fire Initiating Events and Equipment Selection and Internal Fire Cable Selection and Location technical elements and SATISFY the CC-I requirements in HLR-SY-A and HLR-SY-B in Part 2 for Systems Analysis except where the requirements are not applicable with the following clarification: All the SRs in HLR-SY-A and HLR-SY-B in Part 2 are to be addressed in the context of fire scenarios, including effects on system operability/functionality and including fire damage to equipment and associated cabling	For any cases where new system models or split fractions are needed, or existing models or split fractions need to be modified, INCLUDE in the plant response model for internal fire the effects of: *(a)* fire-induced equipment failures *(b)* fire-specific operator actions as identified per the requirements of the Internal Fire Human Reliability Analysis technical element *(c)* fire-induced spurious operations as identified per the requirements of the Internal Fire Initiating Events and Equipment Selection and Internal Fire Cable Selection and Location technical elements and SATISFY the CC-II requirements in HLR-SY-A and HLR-SY-B in Part 2 for Systems Analysis except where the requirements are not applicable with the following clarification: All the SRs in HLR-SY-A and HLR-SY-B in Part 2 are to be addressed in the context of fire scenarios, including effects on system operability/functionality and including fire damage to equipment and associated cabling
PRM-B10	MODIFY the plant response model for internal fire so that systems and equipment included in the internal-events PRA that are potentially vulnerable to fire-induced failure are failed in the most conservative mode, consistent with the applicable accident sequences, including fire-induced spurious operation, if *(a)* the cables have not been routed as per SR CS-A2 and *(b)* the cables have not been routed by assumption (i.e., see SR CS-A4)	
PRM-B11	IDENTIFY any plant response model for internal fire probability input values that either require reanalysis given the fire context or that were not included in the internal-events PRA, excluding any parameters specific to technical elements Internal Fire Scenario Selection and Analysis, Internal Fire Ignition Frequency, Internal Fire Circuit Failure Analysis, and Internal Fire Human Reliability Analysis.	
PRM-B12	For any item identified per SR PRM-B11, SATISFY the CC-I requirements in HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D in Part 2 for Data Analysis except where the requirements are not applicable, with the following clarification: all the SRs under HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D in Part 2 are to be addressed in the context of both random events as well as fire events causing damage to equipment and associated cabling.	For any item identified per SR PRM-B11, SATISFY the CC-II requirements in HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D in Part 2 for Data Analysis except where the requirements are not applicable, with the following clarification: all the SRs under HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D in Part 2 are to be addressed in the context of both random events as well as fire events causing damage to equipment and associated cabling.

Table 4-2.5-3 Supporting Requirements for HLR-PRM-B (Cont'd)

The plant response model for internal fire shall include initiating events induced by internal fires, both fire-induced and random failures of equipment, fire-specific as well as non-fire-related human failures associated with safe shutdown, events in the accident progression sequences (e.g., containment failure modes), and the supporting probability data (including uncertainty) based on the SRs stated under this HLR that parallel, as appropriate, Part 2 for internal-events PRA (HLR-PRM-B).

Index No. PRM-B	Capability Category I	Capability Category II
PRM-B13	IDENTIFY any new accident progression sequences beyond the onset of core damage that would be applicable to the internal fire PRA that were not addressed for LERF estimation in the internal-events PRA.	
PRM-B14	MODEL any new accident progression sequences beyond the onset of core damage identified per SR PRM-B13 to determine the internal fire-induced LERF and SATISFY HLR-LE-A, HLR-LE-B, HLR-LE-C, and HLR-LE-D in Part 2 for LERF Analysis except where the requirements are not applicable with the following clarifications: *(a)* All the SRs under HLR-LE-A, HLR-LE-B, HLR-LE-C, and HLR-LE-D in Part 2 are to be addressed in the context of fire scenarios. *(b)* CC-I requirements in SRs LE-C2 and LE-C6 in Part 2 are to be met in a manner consistent with HLR-FHR-A, HLR-FHR-B, HLR-FHR-C, and HLR-FHR-D (Section 4-2.10). *(c)* SR LE-C6 in Part 2 is to be met in a manner consistent with SR PRM-B9. *(d)* SR LE-C8 in Part 2 is to be met in a manner consistent with SR PRM-B6.	MODEL any new accident progression sequences beyond the onset of core damage identified per SR PRM-B13 to determine the internal fire-induced LERF and SATISFY HLR-LE-A through HLR-LE-D in Part 2 for LERF Analysis except where the requirements are not applicable with the following clarifications: *(a)* All the SRs under HLR-LE-A, HLR-LE-B, HLR-LE-C, and HLR-LE-D in Part 2 are to be addressed in the context of fire scenarios *(b)* CC-II requirements in SRs LE-C2 and LE-C6 in Part 2 are to be met in a manner consistent with HLR-FHR-A, HLR-FHR-B, HLR-FHR-C, and HLR-FHR-D (Section 4-2.10). *(c)* SR LE-C6 in Part 2 is to be met in a manner consistent with SR PRM-B9. *(d)* SR LE-C8 in Part 2 is to be met in a manner consistent with SR PRM-B6.
PRM-B15	IDENTIFY the sources of model uncertainty and assumptions associated with the Internal Fire Plant Response Model analysis (HLR-PRM-A, HLR-PRM-B).	

Table 4-2.5-4 Supporting Requirements for HLR-PRM-C

The documentation of the Internal Fire Plant Response Model shall provide traceability of the work (HLR-PRM-C).

Index No. PRM-C	Capability Category I	Capability Category II
PRM-C1	DOCUMENT the process used in the plant response model for internal fire development specifying the inputs to the Internal Fire Plant Response Model technical element, the applied methods, and the results. The documentation includes, as a minimum, *(a)* the disposition of internal-events PRA peer review exceptions and deficiencies for the internal fire PRA *(b)* the basis for the initiating events included in the plant response model for internal fire *(c)* the basis for modeling of accident progression sequences that are added per SR PRM-B6 and SR PRM-B14 *(d)* any modification performed in the internal-events model logic, including added or modified initiating events, data, Success Criteria, and accident sequences, to represent fire-induced scenarios in the plant response model for internal fire	
PRM-C2	DOCUMENT the Internal Fire Plant Response Model, and SATISFY the documentation requirements in HLR-IE-D in Part 2 for the Initiating Event Analysis, HLR-AS-C in Part 2 for the Accident Sequence Analysis, HLR-SC-C in Part 2 for Success Criteria, HLR-SY-C in Part 2 for Systems Analysis, and HLR-DA-E in Part 2 for Data Analysis as well as Section 4-2.10, with the following clarifications except where the requirements are not applicable: HLR-IE-D in Part 2 is to be met in a manner consistent with HLR-IGN-B of this Standard.	
PRM-C3	DOCUMENT the sources of model uncertainty and assumptions associated with the Internal Fire Plant Response Model (HLR-PRM-A, HLR-PRM-B).	

4-2.6 INTERNAL FIRE SCENARIO SELECTION AND ANALYSIS (FSS)

The objectives of the Internal Fire Scenario Selection and Analysis are to

(a) select a set of fire scenarios for each PAU that has not been screened out and upon which fire-risk estimates will be based

(b) characterize the selected fire scenarios

(c) determine the likelihood and extent of risk-relevant fire damage for each selected fire scenario including

(1) an evaluation of the fire-generated conditions at the target location including fire spread to secondary combustibles

(2) an evaluation of the thermal response of damage targets to the fire-generated conditions

(3) an evaluation of fire detection and suppression activities

(d) examine multicompartment fire scenarios

Table 4-2.6-1 High Level Requirement for Internal Fire Scenario Selection and Analysis (FSS)

Designator	Requirement
HLR-FSS-A	The internal fire PRA shall select sufficient combinations of an ignition source (or group of ignition sources) and damage target sets to represent the fire scenarios for each PAU that has not been screened out and upon which an estimation of the risk contribution (CDF and LERF) will be based.
HLR-FSS-B	The internal fire PRA shall include an analysis of potential fire scenarios leading to the transfer of primary command and control outside the main control room.
HLR-FSS-C	The internal fire PRA shall characterize the factors that will influence the timing and extent of fire damage for each combination of an ignition source and damage target sets selected per HLR-FSS-A.
HLR-FSS-D	The internal fire PRA shall select and apply appropriate fire analysis tools.
HLR-FSS-E	The internal fire PRA shall quantify the conditional probabilities of target damage given fire ignition.
HLR-FSS-F	The internal fire PRA shall search for and analyze risk-relevant ignition sources with the potential for causing fire-induced failure of exposed structural steel.
HLR-FSS-G	The internal fire PRA shall identify multicompartment fire scenarios for which the risk contribution will be estimated.
HLR-FSS-H	The documentation of the Internal Fire Scenario Selection and Analysis shall provide traceability of the work.

Table 4-2.6-2 Supporting Requirements for HLR-FSS-A

The internal fire PRA shall select sufficient combinations of an ignition source (or group of ignition sources) and damage target sets to represent the fire scenarios for each PAU that has not been screened out and upon which an estimation of the risk contribution (CDF and LERF) will be based (HLR-FSS-A).

Index No. FSS-A	Capability Category I	Capability Category II
FSS-A1	In each PAU that has not been screened out within the global analysis boundary, IDENTIFY the ignition sources, both fixed and transient, that are capable of creating fire-induced environmental conditions, including through fire spread, that can cause the failure of at least one fire PRA equipment item or cable (i.e., a risk-relevant damage target).	
FSS-A2	IDENTIFY risk-relevant damage targets in each PAU that has not been screened out within the global analysis boundary.	
FSS-A3	If the exact routing of a cable (or group of cables) has not been established (see SRs CS-A3 and CS-A4), ASSUME that those cables fail for any fire scenario that has a damaging effect on any raceway or conduit where the subject cable cannot be excluded.	
FSS-A4	For each PAU that has not been screened out within the global analysis boundary, SELECT sufficient combinations of a fire-ignition source (or group of ignition sources) and target sets as characteristics of the selected fire scenarios so that the fire-risk contribution can be characterized commensurate with whether it is a risk-significant contributor.	

Table 4-2.6-3 Supporting Requirements for HLR-FSS-B

The internal fire PRA shall include an analysis of potential fire scenarios leading to the transfer of primary command and control outside the main control room (HLR-FSS-B).

Index No. FSS-B	Capability Category I	Capability Category II
FSS-B1	SPECIFY and JUSTIFY the conditions that are assumed to require a transfer of primary command and control outside the main control room. INCLUDE both MCR habitability issues and loss of MCR control functions.	
FSS-B2	SELECT a sufficient number of fire scenarios, either in the MCR or elsewhere, leading to a transfer of primary command and control outside the main control room so that the fire-risk contribution of MCR abandonment can be bounded.	SELECT a sufficient number of fire scenarios, either in the MCR or elsewhere, leading to a transfer of primary command and control outside the main control room so that the fire-risk contribution of MCR abandonment *(a)* can be characterized *(b)* is correlated to specific ignition sources and target sets for risk-significant contributors

Table 4-2.6-4 Supporting Requirements for HLR-FSS-C

The internal fire PRA shall characterize the factors that will influence the timing and extent of fire damage for each combination of an ignition source and damage target sets selected per HLR-FSS-A (HLR-FSS-C).

Index No. FSS-C	Capability Category I	Capability Category II
FSS-C1	For fire scenarios selected in accordance with HLR-FSS-A and HLR-FSS-B, SPECIFY intensity and duration characteristics to the ignition sources that are conservative or bounding.	For ignition sources that are risk-significant contributors and where supported by the current state of practice, PROVIDE a probabilistic representation of *(a)* the effects of ignition source type and location *(b)* the range of fire heat release rate profiles *(c)* the contribution of low-likelihood but potentially more challenging fires For fire scenarios that are risk-significant contributors where a probabilistic representation of the ignition source is not available, SPECIFY the basis for the characterization of the fire-ignition source used in the analysis.
FSS-C2	CHARACTERIZE ignition-source intensity such that the fire is initiated at full-peak intensity (i.e., heat release rate).	For those scenarios that are risk-significant contributors, CHARACTERIZE ignition-source intensity using a time-dependent fire growth profile (i.e., a time-dependent heat release rate) representative of the ignition source.
FSS-C3	CHARACTERIZE the total heat release rate profile of the fire source and secondary combustibles, including fire growth, steady burning, and decay stages, consistent with its risk significance.	

Table 4-2.6-4 Supporting Requirements for HLR-FSS-C (Cont'd)

The internal fire PRA shall characterize the factors that will influence the timing and extent of fire damage for each combination of an ignition source and damage target sets selected per HLR-FSS-A (HLR-FSS-C).

Index No. FSS-C	Capability Category I	Capability Category II
FSS-C4	If a severity factor is applied in the analysis, ENSURE that *(a)* the severity factor remains independent of other quantification factors *(b)* the event set is the same as the set used to estimate fire frequency for any severity factor relying on event data *(c)* the severity factor applied is based on the conservative or bounding conditions and assumptions that could influence whether or not a fire will damage targets for the specific set of fire scenarios to which the severity factor is applied *(d)* a basis supporting the severity factor's determination is stated	USE severity factors for fire scenarios that are risk-significant contributors such that *(a)* the severity factor remains independent of other quantification factors *(b)* if the severity factor relies on insights from event data, the event set is the same as the set used to estimate fire frequency *(c)* the severity factor takes into account the conditions and assumptions that could influence whether or not a fire will damage targets of the specific fire scenario under analysis *(d)* a basis supporting the severity factor's determination is stated
FSS-C5	JUSTIFY that the damage criteria used in the fire PRA are representative of the damage targets associated with each fire scenario.	
FSS-C6	ASSUME target damage occurs when the exposure environment exceeds the damage threshold.	For fire scenarios that are risk-significant contributors where target thermal response analysis would make a material difference to risk estimates, CALCULATE target damage times based on the thermal response of the damage target.
FSS-C7	If raceway fire wraps, other passive fire barrier elements, or active fire barrier elements within a single PAU are credited in the analysis of fire scenarios, *(a)* SPECIFY a basis for their fire-resistance rating *(b)* CONFIRM that the fire wrap or other passive fire-protection features will not be subjected to either mechanical damage or damage from direct flame impingement from a high-hazard ignition source unless the element has been subject to qualification or other proof of performance by analysis or testing under these conditions *(c)* INCLUDE analysis of fire scenarios involving the failure of the credited barrier element	

Table 4-2.6-5 Supporting Requirements for HLR-FSS-D

The internal fire PRA shall select and apply appropriate fire analysis tools (HLR-FSS-D).

Index No. FSS-D	Capability Category I	Capability Category II
FSS-D1	USE analytical, empirical, and/or statistical fire modeling tools that have sufficient capability to model the conditions of interest and only within known limits of applicability.	
FSS-D2	USE conservative assumptions regarding the likelihood and/or extent of fire damage in the analysis of fire scenarios such that the fire-risk contribution of each PAU, which is not screened out, is bounded.	For each fire scenario that is not screened out, USE fire analysis tools sufficient to characterize the risk significance of the fire scenario.
FSS-D3	SPECIFY a basis for fire modeling tool input values used in the analysis, given the context of the fire scenarios being analyzed.	
FSS-D4	For any fire modeling parameters not covered by HLR-FSS-C, USE plant-specific parameter estimates for fire modeling if available; otherwise, use generic information.	
FSS-D5	If neither plant-specific nor generic parameter values are available for fire modeling, USE parameter values for the most similar situation, adjusting if necessary to account for differences, or USE expert judgment consistent with Section 1-4.2 of this Standard and SPECIFY the basis for the choice of parameter values.	
FSS-D6	If statistical models are applied in the fire scenario analyses, SPECIFY a basis for the applied models.	
FSS-D7	SPECIFY a basis for any applied empirical models in the context of the fire scenarios being analyzed by *(a)* citing a referenced document, or *(b)* developing the basis if *(1)* one is not available in referenced documentation (e.g., technical reports describing the empirical models), or *(2)* the empirical models are used outside the recommended scenario conditions	
FSS-D8	EVALUATE the potential for smoke damage to fire PRA equipment on a qualitative basis and INCLUDE the results of this assessment in the definition of fire scenario target sets.	
FSS-D9	COLLECT information on the combinations of fire sources and target sets that were selected per SR FSS-A4, and CONFIRM that these combinations represent the as-built plant conditions for those PAUs that represent risk-significant contributors via walkdown.	
FSS-D10	For PAUs that are risk-significant contributors, CONFIRM by walkdowns that the selected fire scenarios represent the following conditions: *(a)* characteristics of the ignition source that influence fire heat release rate *(b)* the location of damage targets relative to ignition sources *(c)* proximity, type, and configuration of secondary combustibles *(d)* location, type, and physical condition of raceway fire barrier systems *(e)* placement of fixed fire detection and suppression equipment *(f)* physical and ventilation characteristics of the PAU	

Table 4-2.6-6 Supporting Requirements for HLR-FSS-E

The internal fire PRA shall quantify the conditional probabilities of target damage given fire ignition (HLR-FSS-E).

Index No. FSS-E	Capability Category I	Capability Category II
FSS-E1	In crediting fire detection and suppression systems, USE generic estimates of total system unavailability provided that *(a)* the credited system is installed and maintained in accordance with applicable codes and standards *(b)* the credited system is in a fully operable state during plant operation *(c)* if multiple suppression paths are credited, dependencies among the credited paths are modeled, including dependencies associated with recovery of a failed fire suppression system, if such recovery is credited	In crediting fire detection and suppression systems, USE generic estimates of total system unavailability provided that *(a)* the credited system is installed and maintained in accordance with applicable codes and standards *(b)* the credited system is in a fully operable state during plant operation *(c)* if multiple suppression paths are credited, dependencies among the credited paths are modeled, including dependencies associated with recovery of a failed fire suppression system, if such recovery is credited *(d)* plant operating experience has been reviewed and the system has not experienced outlier behavior relative to total system unavailability If outlier behavior relative to system unavailability is detected, CALCULATE the system unavailability and SATISFY the CC-II requirements in HLR-DA-D in Part 2 for Data Analysis, except where the requirements are not applicable.
FSS-E2	INCLUDE an assessment of fire detection and suppression system effectiveness in the context of each fire scenario analyzed, that includes *(a)* the time available to suppress the fire prior to target damage *(b)* specific features of PAU and fire scenario under analysis (e.g., pocketing effects, blockages that might impact plume behaviors or the "visibility" of the fire to detection and suppression systems, and suppression system coverage) *(c)* suitability of the installed system given the nature of the fire source being analyzed	
FSS-E3	For each combination of a fire-ignition source and a target set (e.g., see SR FSS-A4) whose analysis has taken credit for fire suppression prior to fire damage, CALCULATE a point estimate of the nonsuppression probability. For fire scenarios that are risk-significant contributors, CHARACTERIZE the uncertainty in the estimated nonsuppression probability. This characterization could include, for example, specifying the uncertainty range, qualitatively discussing the uncertainty range, or identifying the estimate as conservative or bounding.	For each combination of a fire-ignition source and a target set (e.g., see SR FSS-A4) whose analysis has taken credit for fire suppression prior to fire damage, the following actions apply: *(a)* For fire scenarios that are risk-significant contributors, CALCULATE a mean value of the nonsuppression probability and PROVIDE a probabilistic representation of the uncertainty in the estimated nonsuppression probability. *(b)* For fire scenarios that are not risk-significant contributors, CALCULATE a point estimate value of the nonsuppression probability.
FSS-E4	CONFIRM that the data used to develop the manual nonsuppression probabilities and the corresponding fire-ignition frequency values (see HLR-IGN-A) have been used consistently so as to avoid double counting.	

Table 4-2.6-7 Supporting Requirements for HLR-FSS-F

The internal fire PRA shall search for and analyze risk-relevant ignition sources with the potential for causing fire-induced failure of exposed structural steel (HLR-FSS-F).

Index No. FSS-F	Capability Category I	Capability Category II
FSS-F1	IDENTIFY any locations within the fire PRA global analysis boundary that meet both of the following conditions: *(a)* Exposed structural steel is present *(b)* A high-hazard fire source is present in that location If such locations are identified, SELECT those fire scenarios that could potentially damage, including collapse, the exposed structural steel for each identified location.	
FSS-F2	If scenarios are selected per SR FSS-F1, PERFORM a qualitative assessment of the risk of the selected fire scenarios, including collapse of the exposed structural steel.	If, per SR FSS-F1, one or more scenarios are selected, SPECIFY the technical basis for the criteria associated with structural collapse due to fire exposure and PERFORM a quantitative assessment of the risk of the selected fire scenarios in a manner consistent with HLR-FQ-A, HLR-FQ-B, HLR-FQ-C, HLR-FQ-D, HLR-FQ-E, and HLR-FQ-F, including collapse of the exposed structural steel.

Table 4-2.6-8 Supporting Requirements for HLR-FSS-G

The internal fire PRA shall identify multicompartment fire scenarios for which the risk contribution will be estimated (HLR-FSS-G).

Index No. FSS-G	Capability Category I	Capability Category II
FSS-G1	For fire modeling of single PAUs to the modeling of multicompartment fire scenarios, SATISFY SRs FSS-C1, FSS-C2, FSS-C3, FSS-C4, FSS-C5, FSS-C6, and FSS-C7 except where the requirements are not applicable.	
FSS-G2	For multicompartment fire scenarios, USE the screening criteria per the screening criteria of SCR-2 and SCR-3 from Table 1-1.8-1 to all the PAUs within the global analysis boundaries.	
FSS-G3	For each PAU combination that is not screened out, SELECT a sufficient number of multicompartment fire scenario(s) so that the fire-risk contribution of multicompartment fires can be characterized.	
FSS-G4	When passive fire barriers with a fire-resistance rating are credited in the fire PRA, ENSURE that the credit for resistance against fire-induced failure is consistent with the fire-resistance rating as demonstrated by conformance to applicable test standards.	When passive fire barriers with a fire-resistance rating are credited in the fire PRA: *(a)* ENSURE that the credit for resistance against fire-induced failure is consistent with the fire-resistance rating as demonstrated by conformance to applicable test standards, *and* *(b)* QUANTIFY the random failure probability including reliability and availability
FSS-G5	If passive fire barriers that lack a fire-resistance rating are credited in the fire PRA, SPECIFY the basis for the credit given for resistance against fire-induced failure.	If passive fire barriers that lack a fire-resistance rating are credited in the fire PRA: *(a)* SPECIFY the basis for the credit given including resistance against fire-induced failure *and* *(b)* QUANTIFY the random failure probability including reliability and availability.

Table 4-2.6-8 Supporting Requirements for HLR-FSS-G (Cont'd)

The internal fire PRA shall identify multicompartment fire scenarios for which the risk contribution will be estimated (HLR-FSS-G).

Index No. FSS-G	Capability Category I	Capability Category II
FSS-G6	For any scenario selected per SR FSS-G3, if the adjoining PAUs are separated by active fire-barrier elements, ASSESS qualitatively the effectiveness, reliability, and availability of the active fire barrier element.	For any scenario selected per SR FSS-G3, if the adjoining PAUs are separated by active fire barrier elements *(a)* CALCULATE the reliability and availability of the active fire barrier element *(b)* CONFIRM that the active fire barrier element will be effective given the nature of the fire threat being postulated
FSS-G7	ASSESS qualitatively the potential risk importance of any selected multicompartment fire scenarios.	CALCULATE the risk contribution of any selected multicompartment fire scenarios in a manner consistent with HLR-FQ-A, HLR-FQ-B, HLR-FQ-C, HLR-FQ-D, HLR-FQ-E, and HLR-FQ-F.
FSS-G8	IDENTIFY the sources of model uncertainty and assumptions associated with the Internal Fire Scenario Selection and Analysis (HLR-FSS-A, HLR-FSS-B, HLR-FSS-C, HLR-FSS-D, HLR-FSS-E, HLR-FSS-F, HLR-FSS-G).	

Table 4-2.6-9 Supporting Requirements for HLR-FSS-H

The documentation of the Internal Fire Scenario Selection and Analysis shall provide traceability of the work (HLR-FSS-H).

Index No. FSS-H	Capability Category I	Capability Category II
FSS-H1	DOCUMENT the process used for fire scenario selection. The documentation includes, as a minimum, *(a)* the basis for target damage mechanisms and thresholds used in the analysis, including references for any plant-specific or target-specific performance criteria applied in the analysis *(b)* the basis for the selection of the applied fire modeling tools *(c)* a basis for any statistical and empirical models applied in the analysis, including applicability *(d)* a basis for any plant-specific updates applied to generic statistical models *(e)* the assumptions made related to credited firefighting activities including fire detection, fire suppression systems, and any credit given to manual suppression efforts *(f)* the methodology used to select and quantify scenarios with the potential for causing fire-induced failure of exposed structural steel *(g)* the methodology used to select multicompartment fire scenarios that are potentially risk-significant contributors *(h)* the walkdown process and results	
FSS-H2	For each fire scenario, DOCUMENT the fire growth and damage analysis and related assumptions including *(a)* the nature and characteristics of the ignition source *(b)* the nature and characteristics of the damage target set *(c)* any applied severity factors *(d)* the calculated nonsuppression probability *(e)* the fire modeling tool input values used in the analysis of each fire scenario *(f)* fire modeling output results for each analyzed fire scenario, including the results of parameter uncertainty evaluations (as performed)	
FSS-H3	Document the sources of model uncertainty and assumptions associated with the Internal Fire Scenario Selection and Analysis (HLR-FSS-A, HLR-FSS-B, HLR-FSS-C, HLR-FSS-D, HLR-FSS-E, HLR-FSS-F, HLR-FSS-G).	

4-2.7 INTERNAL FIRE IGNITION FREQUENCY (IGN)

The objectives of Internal Fire Ignition Frequency are

(a) to establish the plantwide frequency of internal fires of various types by using generic data updated when appropriate with plant-specific data for a nuclear power plant and

(b) to apportion fire frequencies to specific plant PAUs and/or fire scenarios as defined by the Internal Fire Scenario Selection and Analysis technical element (see Section 4-2.6).

Fire events that have occurred in the nuclear power industry serve as the basis for establishing fire-ignition frequencies and associated uncertainties. Applicable data from nonnuclear power industry sources are used only when there is no similar experience in the nuclear power industry and with appropriate justification.

Table 4-2.7-1 High Level Requirement for Internal Fire Ignition Frequency (IGN)

Designator	Requirement
HLR-IGN-A	The internal fire PRA shall estimate fire-ignition frequencies for every PAU that has not been qualitatively screened out.
HLR-IGN-B	The documentation of the Internal Fire Ignition Frequency shall provide traceability of the work.

Table 4-2.7-2 Supporting Requirements for HLR-IGN-A

The internal fire PRA shall estimate fire-ignition frequencies for every PAU that has not been qualitatively screened out (HLR-IGN-A).

Index No. IGN-A	Capability Category I	Capability Category II
IGN-A1	Except as allowed by SRs IGN-A2 and IGN-A3, USE current nuclear power industry event history that includes power plants of similar type, characteristics, and vintages to establish ignition frequencies. SPECIFY the basis for the exclusion of data judged to be nonapplicable (e.g., due to changes in industry practices).	
IGN-A2	Except as allowed by SR IGN-A3, USE applicable data from nonnuclear power industry sources only when there is no similar experience in the nuclear power industry. JUSTIFY all nonnuclear power industry sources used for establishing fire-ignition frequencies by demonstrating the applicability of information stated in those sources to the specific ignition source being studied. In justifying the use of nonnuclear power industry data, CONFIRM that *(a)* applicable nuclear industry data do not exist; a description of the data being applied, including its source, is documented; discussion of the data analysis approach and methods used to estimate per-reactor-year fire frequencies is documented; and the data are applicable to nuclear power plant conditions and the fire scenario(s) being analyzed *(b)* the underlying data set is applicable to the specific ignition source being studied *(c)* the underlying data set is applicable to nuclear power plant conditions and the fire scenario(s) being analyzed *(d)* the scope and completeness of the underlying data set are adequate to support robust statistical treatment *(e)* the total population base and equivalent years of operating experience represented by the underlying data set can be quantified *(f)* the fire frequencies calculated are consistent with and have properly analyzed dependencies with or are independent from other aspects of the fire PRA, including, in particular, any applied fire severity (e.g., fire severity factor) treatments and/or any mitigation credit applied for fire detection and suppression prior to target damage including the analysis of both timing and effectiveness *(g)* the underlying data set and all analyses performed are available for review	
IGN-A3	In cases where nuclear power industry and nonnuclear industry data are not available, SATISFY expert judgment requirements from Section 1-4.2 of this Standard.	
IGN-A4	REVIEW plant-specific experience for fire event outlier experience and PERFORM a plant-specific fire frequency update if outliers are found.	

Table 4-2.7-2 Supporting Requirements for HLR-IGN-A (Cont'd)

The internal fire PRA shall estimate fire-ignition frequencies for every PAU that has not been qualitatively screened out (HLR-IGN-A).

Index No. IGN-A	Capability Category I	Capability Category II
IGN-A5	ESTIMATE generic fire-ignition frequencies or plant-specific fire frequency updates on a reactor-year basis (generic fire frequencies are typically reported on this same basis). INCLUDE in the fire frequency estimation the plant availability, such that the frequencies are weighted by the fraction of time the plant is at-power.	
IGN-A6	When combining evidence from generic and plant-specific data, USE a Bayesian update process or equivalent statistical process and SATISFY the CC-I requirements in SR DA-D1 in Part 2 for Data Analysis, except where the requirements are not applicable.	When combining evidence from generic and plant-specific data, USE a Bayesian update process or equivalent statistical process and SATISFY the CC-II requirements in SR DA-D1 in Part 2 for Data Analysis, except where the requirements are not applicable.
IGN-A7	USE a plantwide consistent methodology for both fixed and transient ignition sources based on parameters that are expected to influence the likelihood of ignition to apportion high-level ignition frequencies to estimate PAU or ignition source-level frequencies.	
IGN-A8	SPECIFY an ignition frequency greater than zero to every plant PAU that has not been qualitatively screened out.	
IGN-A9	CALCULATE a point estimate for the ignition frequencies. CHARACTERIZE the uncertainty for those ignition frequencies associated with fire scenarios that are risk-significant contributors. This characterization could include, for example, specifying the uncertainty range, qualitatively discussing the uncertainty range, or identifying the estimate as conservative or bounding.	CALCULATE a mean value for the ignition frequencies for the fire scenarios that are significant contributors. PROVIDE a probabilistic representation of the uncertainty of the parameter estimates of ignition frequencies for the fire scenarios that are risk-significant contributors. If using expert judgment, SATISFY the requirements of Section 1-4.2. For the fire scenarios that are non-risk-significant contributors, CALCULATE point estimates.
IGN-A10	IDENTIFY the sources of model uncertainty and assumptions associated with the Internal Fire Ignition Frequency (HLR-IGN-A).	

Table 4-2.7-3 Supporting Requirements for HLR-IGN-B

The documentation of the Internal Fire Ignition Frequency shall provide traceability of the work (HLR-IGN-B).

Index No. IGN-B	Capability Category I	Capability Category II
IGN-B1	DOCUMENT the process used in the ignition frequency analysis specifying the inputs to the Internal Fire Ignition Frequency technical element, the applied methods, and the results. Address the following and other details needed to fully document how the set of SRs are satisfied: *(a)* references for fire events and fire-ignition frequency sources used *(b)* the apportioning methodology and bases of selected values *(c)* the plant-specific frequency updating process and results including the selected plant-specific events, the basis for the selection or exclusion of events, the analysis supporting the plant-specific reactor-years, and the Bayesian process for updating generic frequencies	
IGN-B2	DOCUMENT the sources of model uncertainty and assumptions associated with the ignition frequency analysis (SR IGN-A10).	

4-2.8 INTERNAL FIRE CIRCUIT FAILURE ANALYSIS (CF)

The objectives of Internal Fire Circuit Failure Analysis are to

(a) refine the understanding and analysis of fire-induced circuit failures on an individual fire scenario basis

(b) ensure that the consequences of each fire scenario on the damaged cables and circuits have been addressed

The overall scope of circuits examined in the fire PRA is addressed in Sections 4-2.2 and 4-2.3. However, the Internal Fire Cable Selection and Location technical element addressed in Section 4-2.3 contains some simplifications and was performed without consideration of certain limiting cable failure combinations and circuit failure modes. Accordingly, certain cable failure combinations or failure modes might not actually jeopardize the desired equipment function on an individual fire-scenario basis. In addition, the specific circuit failure mode of concern might have a conditional probability of occurrence given circuit failure that is not unity. A circuit analysis is performed given these circuit failures to determine the scope and extent of equipment functional impacts and the conditional probability of the specific circuit failure mode needed to cause those impacts.

The scope of the Internal Fire Circuit Failure Analysis requirements is limited to only those elements of fire-induced consequences that are attributable to cable and circuit failures.

Table 4-2.8-1 High Level Requirement for Internal Fire Circuit Failure Analysis (CF)

Designator	Requirement
HLR-CF-A	The internal fire PRA shall determine the applicable conditional probability of the cable and circuit failure mode(s) that would cause equipment functional failure and/or undesired spurious operation based on the equipment failure modes as modeled in the plant response model for internal fire.
HLR-CF-B	The documentation of the Internal Fire Circuit Failure Analysis shall provide traceability of the work.

Table 4-2.8-2 Supporting Requirements for HLR-CF-A

The internal fire PRA shall determine the applicable conditional probability of the cable and circuit failure mode(s) that would cause equipment functional failure and/or undesired spurious operation based on the equipment failure modes as modeled in the plant response model for internal fire (HLR-CF-A).

Index No. CF-A	Capability Category I	Capability Category II
CF-A1	SPECIFY conservative or bounding failure-mode probabilities to components consistent with generic industry-wide values.	For fire scenarios that are risk-significant contributors, SPECIFY the component failure-mode probabilities consistent with *(a)* the industry-wide cable failure mode generic values, *(b)* the cables failed in the fire scenario, and *(c)* the characteristics of the damaged circuits. For fire scenarios that are risk-significant contributors and that include spurious operation component failure modes that would be impacted by the consideration of hot short duration, CREDIT the mitigating effects of limited hot short duration in the analysis. For fire scenarios that are non-risk-significant contributors, SPECIFY bounding failure mode probabilities to components consistent with generic industry-wide values.

Table 4-2.8-2 Supporting Requirements for HLR-CF-A (Cont'd)

The internal fire PRA shall determine the applicable conditional probability of the cable and circuit failure mode(s) that would cause equipment functional failure and/or undesired spurious operation based on the equipment failure modes as modeled in the plant response model for internal fire (HLR-CF-A).

Index No. CF-A	Capability Category I	Capability Category II
CF-A2	CALCULATE a point estimate for the failure mode probability values specified per SR CF-A1. CHARACTERIZE the uncertainty for those probability values associated with fire scenarios that are risk-significant contributors. This characterization could include, for example, specifying the uncertainty range, qualitatively discussing the uncertainty range, or identifying the estimate as conservative or bounding.	For the fire scenarios that are risk-significant contributors, CALCULATE a mean value for the failure mode probability values specified per SR CF-A1 and the duration probabilities specified per SR CF-A1, and PROVIDE a probabilistic representation of the uncertainty of the parameter estimates of the probability values for the fire scenarios that are risk-significant contributors. For the fire scenarios that are not risk-significant, CALCULATE point estimates and CHARACTERIZE the uncertainty for the failure mode probability and duration values. This characterization could include, for example, specifying the uncertainty range, qualitatively discussing the uncertainty range, or identifying the estimate as conservative or bounding.
CF-A3	IDENTIFY the sources of model uncertainty and assumptions (as identified in SRs under HLR-CF-A) associated with the Internal Fire Circuit Failure Analysis (HLR-CF-A).	

Table 4-2.8-3 Supporting Requirements for HLR-CF-B

The documentation of the Internal Fire Circuit Failure Analysis provides traceability of the work (HLR-CF-B).

Index No. CF-B	Capability Category I	Capability Category II
CF-B1	DOCUMENT the process used in the Internal Fire Circuit Analysis, specifying the inputs to the Internal Fire Circuit Failure Analysis technical element, the applied methods, and the results. The documentation includes, as a minimum, *(a)* the basis for each circuit failure probability *(b)* the basis for any hot short duration credited in the plant response model *(c)* the uncertainty for each circuit failure probability and hot short duration probability	
CF-B2	DOCUMENT the sources of model uncertainty and assumptions associated with the Internal Fire Circuit Analysis (HLR-CF-A).	

4-2.9 INTERNAL FIRE HUMAN RELIABILITY ANALYSIS (FHR)

The objectives of the Internal Fire Human Reliability Analysis technical element are to

(a) identify the post-initiator human actions and resulting HFEs to be included in the internal fire PRA

(b) quantify the human error probabilities (HEPs) for these HFEs

In this technical element, any prior post-initiator HFEs adopted for use in (or imported directly into) the fire PRA (e.g., from the internal-events PRA that has been assessed against Part 2) need to be modified to include fire location and fire scenario-specific changes in assumptions, modeling structure, and performance-shaping factors. Additionally, HFEs need to be included in the fire PRA to address the use of procedures that

(a) are not modeled in other analyses

(b) direct special actions that the operators take to maintain acceptable plant configurations and achieve safe shutdown given a fire.

Pre-initiator HFEs affecting operability/functionality of fire-protection systems, features, and program elements are inherently addressed under other parts/

technical elements of this Standard that are assumed to rely on a combination of historical and experimental data with regard to operability/functionality of fire-protection systems (active and passive) including fire suppression and fire barriers that include pre-initiator human errors. Thus, no specific requirements are stated here with regard to analysis of pre-initiator HFEs unique to fire-related issues. This lack of requirements does not prevent a user from performing pre-initiator Internal Fire Human Reliability Analysis of these possible errors if it is decided to do so. Under those circumstances, the identification and quantification of such errors should follow Part 2 requirements for pre-initiator HFEs used for internal-events PRAs.

Table 4-2.9-1 High Level Requirement for Internal Fire Human Reliability Analysis (FHR)

Designator	Requirement
HLR-FHR-A	The internal fire PRA shall identify new human actions relevant to the sequences in the plant response model for internal fire.
HLR-FHR-B	The internal fire PRA shall include events where appropriate in the fire PRA associated with any newly identified human actions per HLR-FHR-A.
HLR-FHR-C	The internal fire PRA shall quantify HEPs accounting for the plant-specific and scenario-specific influences on human performance, particularly including the effects of fires, and address potential dependencies.
HLR-FHR-D	The internal fire PRA shall include recovery actions only if the action has been demonstrated to be plausible and feasible for those scenarios to which it applies, particularly accounting for the effects of fires.
HLR-FHR-E	The documentation of the Internal Fire Human Reliability Analysis shall provide traceability of the work.

Table 4-2.9-2 Supporting Requirements for HLR-FHR-A

The internal fire PRA shall identify new human actions relevant to the sequences in the plant response model for internal fire (HLR-FHR-A).

Index No. FHR-A	Capability Category I	Capability Category II
FHR-A1	For each fire scenario, IDENTIFY any new fire-specific safe-shutdown actions and SATISFY HLR-HR-E in Part 2 for Human Reliability Analysis except where the requirements are not applicable, with the following clarifications: *(a)* Where SR HR-E1 discusses procedures, it is to be extended to procedures for responding to fires. *(b)* Where SR HR-E1 mentions "in the context of the accident scenarios," specific attention is to be given to the fact that these are fire scenarios.	For each fire scenario, IDENTIFY any new fire-specific safe-shutdown actions and SATISFY HLR-HR-E in Part 2 for Human Reliability Analysis except where the requirements are not applicable, with the following clarifications: *(a)* Where SR HR-E1 discusses procedures, it is to be extended to procedures for responding to fires. *(b)* Where SR HR-E1 mentions "in the context of the accident scenarios," specific attention is to be given to the fact that these are fire scenarios. For fire scenarios, IDENTIFY any new, undesired operator actions that could result from spurious indications resulting from fire-induced failure of a single instrument, per SR ES-C2.
FHR-A2	REVIEW the interpretation of the procedures associated with actions identified in SR FHR-A1 with plant operations or training personnel to confirm that the interpretation is consistent with plant operational and training practices.	USE talk-throughs (i.e., review in detail) with plant operations and training personnel to confirm that the interpretation of the procedures relevant to actions identified in SR FHR-A1 is consistent with plant operational and training practices.

Table 4-2.9-3 Supporting Requirements for HLR-FHR-B

The internal fire PRA shall include events where appropriate in the fire PRA associated with any newly identified human actions per HRL-FHR-A (HLR-FHR-B).

Index No. FHR-B	Capability Category I	Capability Category II
FHR-B1	INCLUDE new fire-related safe-shutdown HFEs corresponding to the actions identified per SR FHR-A1 in the plant response model for internal fire, and SATISFY CC-I requirements in HLR-HR-F in Part 2 for Human Reliability Analysis except where the requirements are not applicable.	INCLUDE new fire-related safe-shutdown HFEs corresponding to the actions identified per SR FHR-A1 in the plant response model for internal fire, and SATISFY CC-II requirements in HLR-HR-F in Part 2 for Human Reliability Analysis except where the requirements are not applicable.
FHR-B2	DEFINE the fire PRA HFEs, including both those retained from the internal-events analysis and those identified per SR FHR-B1, and SATISFY the CC-I requirements in SR HR-F2 in Part 2 for Human Reliability Analysis, except where the requirements are not applicable.	DEFINE the fire PRA HFEs, including both those retained from the internal-events analysis and those identified per SR FHR-B1, and SATISFY the CC-II requirements in SR HR-F2 in Part 2 for Human Reliability Analysis, except where the requirements are not applicable.

Table 4-2.9-4 Supporting Requirements for HLR-FHR-C

The internal fire PRA shall quantify HEPs accounting for the plant-specific and scenario-specific influences on human performance, particularly including the effects of fires, and address potential dependencies (HLR-FHR-C).

Index No. FHR-C	Capability Category I	Capability Category II
FHR-C1	CALCULATE the HEPs for all HFEs by addressing relevant fire-related effects using conservative estimates (e.g., screening values). For the calculation of HEPs, SATISFY the CC-I requirements in HLR-HR-G in Part 2 for Human Reliability Analysis except where the requirements are not applicable, with the following clarification: attention is to be given to how the fire situation alters any previous assessments in nonfire analyses as to the influencing factors and the timing considerations covered in SRs HR-G1, HR-G3, HR-G4, and HR-G5 in Part 2.	CALCULATE the HEPs for all HFEs by addressing relevant fire-related effects using detailed analyses for HFEs that are risk-significant contributors and conservative estimates (e.g., screening values) for the remaining HFEs. For the calculation of HFEs, SATISFY the CC-II requirements in HLR-HR-G in Part 2 for Human Reliability Analysis except where the requirements are not applicable, with the following clarification: attention is to be given to how the fire situation alters any previous assessments in nonfire analyses as to the influencing factors and the timing considerations covered in SRs HR-G1, HR-G3, HR-G4, and HR-G5 in Part 2.

Table 4-2.9-5 Supporting Requirements for HLR-FHR-D

The internal fire PRA shall include recovery actions only if the action has been demonstrated to be plausible and feasible for those scenarios to which it applies, particularly including the effects of fires (HLR-FHR-D).

Index No. FHR-D	Capability Category I	Capability Category II
FHR-D1	IDENTIFY fire-specific recovery actions and SATISFY SR HR-H1 in Part 2, and QUANTIFY the corresponding HEP values including relevant fire-related effects, including any effects that may preclude a recovery action or alter the manner in which it is accomplished, and SATISFY SRs HR-H2 and HR-H3 in Part 2 for Human Reliability Analysis except where the requirements are not applicable.	
FHR-D2	IDENTIFY the sources of model uncertainty and assumptions associated with Internal Fire Human Reliability Analysis (HLR-FHR-A, HLR-FHR-B, HLR-FHR-C, HLR-FHR-D).	

Table 4-2.9-6 Supporting Requirements for HLR-FHR-E

The documentation of the Internal Fire Human Reliability Analysis shall provide traceability of the work (HLR-FHR-E).

Index No. FHR-E	Capability Category I	Capability Category II
FHR-E1	DOCUMENT the process used in the Internal Fire Human Reliability Analysis specifying the inputs, the applied methods, and the results. The documentation includes, as a minimum, *(a)* the treatment of plant-specific and scenario-specific influences on human reliability, particularly including the effects of fires *(b)* new human actions and recovery actions modeled in the internal fire PRA *(c)* the identification and quantification of the HFEs/HEPs SATISFY HLR-HR-I except where the requirements are not applicable.	
FHR-E2	DOCUMENT the sources of model uncertainty and assumptions associated with the Internal Fire Human Reliability Analysis (HLR-FHR-A, HLR-FHR-B, HLR-FHR-C, HLR-FHR-D).	

4-2.10 INTERNAL FIRE RISK QUANTIFICATION (FQ)

The objectives of Internal Fire Risk Quantification are to

(a) quantify the internal fire-induced CDF and LERF contributions to plant risk

(b) understand what are the risk-significant contributors to the internal fire-induced CDF and LERF

(c) identify, assess, and quantify analysis uncertainties

The final fire risk is determined on the basis of quantifying the plant response model for internal fire developed per the requirements in Section 4-2.5, having integrated the results of all the other technical elements of the fire PRA.

The approach to quantification and the quantified risk measures are virtually the same as are specified for internal-events PRA results per Part 2 but are modified to also include results as to the significant fires (and fire scenarios) and fire locations (e.g., compartments). This modified approach ensures that the quantified results are performed in a way to provide fire-unique related insights (e.g., fire scenarios that are risk-significant contributors).

Table 4-2.10-1 High Level Requirement for Internal Fire Risk Quantification (FQ)

Designator	Requirement
HLR-FQ-A	The internal fire-induced CDF shall be quantified.
HLR-FQ-B	The internal fire-induced CDF quantification shall use appropriate models and codes and a truncation level sufficiently low to show convergence and shall include method-specific limitations and features.
HLR-FQ-C	Model quantification shall determine that all identified dependencies are addressed appropriately.
HLR-FQ-D	Internal fire-induced LERF shall be quantified.
HLR-FQ-E	The internal fire-induced CDF and LERF quantification results shall be reviewed for correctness, completeness, and consistency. The risk-significant contributors to CDF and LERF, such as fires and their corresponding plant initiating events, fire locations, accident sequences, basic events (equipment unavailabilities and HFEs), plant damage states, containment challenges, and failure modes, shall be identified. The results shall be traceable to the inputs and assumptions made in the internal fire PRA.
HLR-FQ-F	Uncertainties in the internal fire PRA results shall be characterized. Sources of model uncertainty and related assumptions shall be identified and their potential impact on the results understood.
HLR-FQ-G	The documentation of the Internal Fire Risk Quantification shall provide traceability of the work and interpretation of the risk profile for the plant.

Table 4-2.10-2 Supporting Requirements for HLR-FQ-A

The internal fire-induced CDF shall be quantified (HLR-FQ-A).

Index No. FQ-A	Capability Category I	Capability Category II
FQ-A1	If quantitative screening is performed, SATISFY the CDF screening criteria in SCR-2 from Table 1-1.8-1 to screen out internal fire scenarios from the final internal fire PRA CDF model (i.e., quantitative screening).	
FQ-A2	For each fire scenario that will be quantified as a contributor to internal fire-induced plant CDF, MODEL the equipment and cable failures as basic events or as impacts on existing basic events in the fire PRA plant response model.	
FQ-A3	For each fire scenario that will be quantified as a contributor to internal fire-induced plant CDF, IDENTIFY the corresponding initiating event or events in the plant response model for internal fire (e.g., general transient, loss of off-site power) and JUSTIFY the selection based on the fire-induced damage associated with the fire scenario.	
FQ-A4	For each fire scenario that will be quantified as a contributor to internal fire-induced plant CDF, INCLUDE the scenario-specific quantification factors (i.e., the factors obtained per requirements of technical elements Internal Fire Circuit Failure Analysis and Internal Fire Human Reliability Analysis, and SRs FQ-A2 and FQ-A3) in the fire PRA plant response model.	
FQ-A5	CALCULATE the internal fire-induced CDF, and SATISFY the CC-I requirements in HLR-QU-A in Part 2 for quantification except where the requirements are not applicable, with the following clarifications: *(a)* Quantification is to include the fire-ignition frequency per the requirements of the Internal Fire Ignition Frequency technical element (see Section 4-2.7) and fire-specific conditional damage probability factors per HLR-FSS-A, HLR-FSS-B, HLR-FSS-C, HLR-FSS-D, HLR-FSS-E, HLR-FSS-F, HLR-FSS-G, and HLR-FSS-H. *(b)* Quantification is to include the quantification factors per SR FQ-A4. *(c)* SR QU-A5 in Part 2 is to be met based on meeting HLR-FHR-D.	CALCULATE the internal fire-induced CDF, and SATISFY the C-II requirements in HLR-QU-A in Part 2 for quantification except where the requirements are not applicable with the following clarifications: *(a)* Quantification is to include the fire-ignition frequency per the requirements of the Internal Fire Ignition Frequency technical element (see Section 4-2.7) and fire-specific conditional damage probability factors per HLR-FSS-A, HLR-FSS-B, HLR-FSS-C, HLR-FSS-D, HLR-FSS-E, HLR-FSS-F, HLR-FSS-G, and HLR-FSS-H. *(b)* Quantification is to include the quantification factors per SR FQ-A4. *(c)* Supporting SR QU-A5 in Part 2 is to be met based on meeting HLR-FHR-D.

Table 4-2.10-3 Supporting Requirements for HLR-FQ-B

The internal fire-induced CDF quantification shall use appropriate models and codes and a truncation level sufficiently low to show convergence and shall include method-specific limitations and features (HLR-FQ-B).

Index No. FQ-B	Capability Category I	Capability Category II
FQ-B1	PERFORM the quantification and SATISFY the CC-I requirements in HLR-QU-B in Part 2 for quantification except where the requirements are not applicable.	PERFORM the quantification and SATISFY the CC-II requirements in HLR-QU-B in Part 2 for quantification except where the requirements are not applicable.

Table 4-2.10-4 Supporting Requirements for HLR-FQ-C

Model quantification shall determine that all identified dependencies are addressed appropriately (HLR-FQ-C).

Index No. FQ-C	Capability Category I	Capability Category II
FQ-C1	INCLUDE dependencies during the plant response model for internal fire quantification and SATISFY the CC-I requirements in HLR-QU-C in Part 2 for quantification except where the requirements are not applicable.	INCLUDE dependencies during the plant response model for internal fire quantification and SATISFY the CC-II requirements in HLR-QU-C in Part 2 for quantification except where the requirements are not applicable.

Table 4-2.10-5 Supporting Requirements for HLR-FQ-D

Internal fire-induced LERF shall be quantified (HLR-FQ-D).

Index No. FQ-D	Capability Category I	Capability Category II
FQ-D1	If quantitative screening is performed, SATISFY the LERF screening criteria in SCR-2 from Table 1-1.8-1 to screen out internal fire scenarios from the final fire PRA LERF model (i.e., quantitative screening).	
FQ-D2	CALCULATE LERF using the plant response model for internal fire and SATISFY the CC-I requirements in HLR-LE-E in Part 2 for LERF Analysis consistent with the requirements of the Internal Fire Plant Response Model and Internal Fire Risk Quantification technical elements of Part 4 except where the requirements are not applicable.	CALCULATE LERF using the plant response model for internal fire and SATISFY the C-II requirements in HLR-LE-E in Part 2 for LERF Analysis consistent with the requirements of the Internal Fire Plant Response Model and Internal Fire Risk Quantification technical elements of Part 4 except where the requirements are not applicable.

Table 4-2.10-6 Supporting Requirements for HLR-FQ-E

The internal fire-induced CDF and LERF quantification results shall be reviewed for correctness, completeness, and consistency. The risk-significant contributors to CDF and LERF, such as fires and their corresponding plant initiating events, fire locations, accident sequences, basic events (equipment unavailabilities and HFEs), plant damage states, containment challenges, and failure modes, shall be identified. The results shall be traceable to the inputs and assumptions made in the internal fire PRA (HLR-FQ-E).

Index No. FQ-E	Capability Category I	Capability Category II
FQ-E1	IDENTIFY risk-significant contributors, and SATISFY the CC-I requirements in HLR-QU-D, SRs LE-F1 and LE-F2 in Part 2, except where the requirements are not applicable, with the following clarifications: *(a)* CC-I requirements in SRs QU-D6 and QU-D7 of Part 2 are to be met including identification of which fire scenarios and which PAUs (consistent with the level of resolution of the fire PRA, e.g., fire area or fire compartment) are risk-significant contributors. *(b)* SR QU-D7 of Part 2 is to be met, recognizing that "component" in Part 2 is generally equivalent to "equipment" in Part 4. *(c)* CC-I requirement in SR QU-D4 of Part 2 for comparison to similar plants is not applicable.	IDENTIFY risk-significant contributors and SATISFY the CC-II requirements in HLR-QU-D, SRs LE-F1 and LE-F2 in Part 2, except where the requirements are not applicable, with the following clarifications: *(a)* CC-II requirements in SRs QU-D6 and QU-D7 of Part 2 are to be met including identification of which fire scenarios and which PAUs (consistent with the level of resolution of the fire PRA, e.g., fire area or fire compartment) are risk-significant contributors. *(b)* SR QU-D7 of Part 2 is to be met, recognizing that "component" in Part 2 is generally equivalent to "equipment" in Part 4. *(c)* CC-II requirement in SR QU-D4 of Part 2 for comparison to similar plants is not applicable.

Table 4-2.10-7 Supporting Requirements for HLR-FQ-F

Uncertainties in the fire PRA results shall be characterized. Sources of model uncertainty and related assumptions shall be identified and their potential impact on the results understood (HLR-FQ-F).

Index No. FQ-F	Capability Category I	Capability Category II
FQ-F1	PERFORM an uncertainty analysis for the fire PRA and SATISFY the CC-I requirements in HLR-QU-E in Part 2 for quantification except where the requirements are not applicable.	PERFORM an uncertainty analysis for the fire PRA and SATISFY the CC-II requirements in HLR-QU-E in Part 2 for quantification except where the requirements are not applicable.
FQ-F2	IDENTIFY the sources of model uncertainty and assumptions associated with the Internal Fire Risk Quantification analysis (HLR-FQ-A, HLR-FQ-B, HLR-FQ-C, HLR-FQ-D, HLR-FQ-E, HLR-FQ-F).	

Table 4-2.10-8 Supporting Requirements for HLR-FQ-G

The documentation of the Internal Fire Risk Quantification shall provide traceability of the work and provide interpretation of the risk profile for the plant (HLR-FQ-G).

Index No. FQ-G	Capability Category I	Capability Category II
FQ-G1	DOCUMENT the process used in the internal fire PRA quantification analysis specifying the inputs to the Internal Fire Risk Quantification technical element, the applied method, and the results including the fire scenarios and PAUs that are risk-significant contributors. SATISFY the documentation requirements in SRs QU-F1, QU-F2, LE-G1, and LE-G2 in Part 2 except where the requirements are not applicable.	
FQ-G2	DOCUMENT the sources of model uncertainty and assumptions associated with the Internal Fire Risk Quantification (HLR-FQ-A, HLR-FQ-B, HLR-FQ-C, HLR-FQ-D, HLR-FQ-E, HLR-FQ-F).	
FQ-G3	DOCUMENT limitations in the quantification process that would impact applications.	

NONMANDATORY APPENDIX 4-A NOTES AND EXPLANATORY MATERIAL

4-A.1 ORGANIZATION AND CONTENT

This Nonmandatory Appendix provides notes and general explanatory material tied to specific SRs as stated in Part 4 of this Standard. The material contained in this Appendix is nonmandatory and, as such, does not establish new requirements: rather, the material is intended to clarify the intent of an SR, explain terminologies that might be used in an SR, and/or provide examples of analysis approaches that would meet the intent of the SR.

The explanatory material, presented in Section 4-A.2, is organized by technical element and then by SR number. For example, Section 4-A.2.2 provides explanatory material for the technical element Internal Fire Initiating Events and Equipment Selection. Subsections under Section 4-A.2.2 are associated with those SRs that include explanatory material. Note that not all SRs include explanatory material, so the SR-specific subsections do not represent a complete set for any given technical element.

The tables that follow provide commentary and explanations that may be useful to the analysts performing various activities associated with the PRA. It is emphasized that, due to the current and evolving nature of the state of practice and experience related to PRA, there is diversity in the approaches described in these commentaries, and these commentaries may be updated over time. The resources below are provided for information and, individually, should not be interpreted as providing definitive or authoritative references for meeting the requirements of this Standard. This list is not offered as being exhaustive. Inclusion of these references does not constitute their endorsement by this Standard.

4-A.2 COMMENTARY TO INTERNAL FIRE PRA TECHNICAL ELEMENTS AND REQUIREMENTS

4-A.2.1 Commentary to Internal Fire Plant Boundary Definition and Partitioning (PP)

Table 4-A.2.1-1 Commentary to High Level Requirements for Internal Fire Plant Boundary Definition and Partitioning (PP)

Designator	Commentary
HLR-PP-A	No commentary provided.
HLR-PP-B	The definition of PAU in Section 1-2.2 purposely relaxes the criteria relative to the degree of fire confinement below those used for “fire areas” as defined in 10CFR50 Appendix R [4-A-9]. For PAU, open leakage paths to other PAUs are allowable. The phrase “substantially contained” means that *(a)* the direct spread of fire between PAUs is unlikely even under the most severe fire conditions possible *(b)* fire-induced damage to potential damage targets will be confined to a single PAU except under the most severe possible fire conditions The potential for fire-induced damage to targets in multiple PAUs is analyzed per HLR-FSS-G.
HLR-PP-C	No commentary provided.

Table 4-A.2.1-2 Commentary to Supporting Requirements for HLR-PP-A

Index No. PP-A	Commentary
PP-A1	The intent of this requirement is to include sister unit locations that meet the selection criteria as stated. The intent of this requirement is that the global analysis boundary will include locations that may contain fire sources that could threaten equipment included in the plant response model for internal fire or related cables by virtue of a multicompartment fire scenario but that may not themselves contain included equipment or cable items.

Table 4-A.2.1-3 Commentary to Supporting Requirements for HLR-PP-B

Index No. PP-B	Commentary
PP-B1	No commentary provided.
PP-B2	The intent of SR PP-B2 is to allow an analysis to credit partitioning features that have a specific fire-endurance rating in the plant partitioning analysis without further justification, subject only to the restriction imposed by SR PP-B4. However, plant partitioning may also, with justification, credit partitioning features that lack a specific fire-endurance rating (nonrated elements), such as spatial separation or nonrated structural elements. Volume 2, Chapter 1 of EPRI TR-1011989 NUREG/CR-6850 [4-A-1] discusses criteria that may be applied in justifying decisions related to spatial separation, active fire barrier elements, and partitioning features that lack a fire-resistance rating.
PP-B3	No commentary provided.
PP-B4	No commentary provided.
PP-B5	When determining the scope and details of the walkdown, it is important that the intent of the walkdown be considered. The intent is to identify items that invalidate modeling in the PRA to such an extent that the model does not reasonably represent the as-built, as-operated plant. In keeping with this intent, it is acceptable that conditions that can be justified as not likely to affect the results (i.e., will not change the risk profile or insights) do not need to be validated. As such, and per Inquiry 20-2435 [4-A-13], it is not required that 100% walkdown be performed if adequate justification can be provided that a lesser scope will suffice. Various justifications could be considered valid, but they must show *(a)* that items that could have a significant impact were walked down and *(b)* that those items not walked down could not have a significant impact. The following are examples of possible justifications: *(a) Bounding Risk Impact:* If the importance measure of an item is low, such that even if the item were assumed failed all the time, the PRA results would not meaningfully change. *(b) Adequacy of Documentation:* There is a sufficient weight of evidence, through drawings, photos/videos, analyses, or interviews with knowledgeable plant staff, that the conditions are as assumed in the PRA. *(c) Impact of Possible Discoveries:* Given past experience with the types of deviations typically found during walkdowns, it is not credible or likely that a deviation would be found that could affect the conditions assumed in the PRA to the extent required to meaningfully change the results.
PP-B6	No commentary provided.
PP-B7	No commentary provided.

Table 4-A.2.1-4 Commentary to Supporting Requirements for HLR-PP-C

Index No. PP-C	Commentary
PP-C1	No commentary provided.
PP-C2	No commentary provided.

4-A.2.2 Commentary to Internal Fire Initiating Events and Equipment Selection (ES)

Table 4-A.2.2-1 Commentary to High Level Requirements for Internal Fire Initiating Events and Equipment Selection (ES)

Designator	Commentary
HLR-ES-A	No commentary provided.
HLR-ES-B	No commentary provided.
HLR-ES-C	No commentary provided.
HLR-ES-D	No commentary provided.

Table 4-A.2.2-2 Commentary to Supporting Requirements for HLR-ES-A

Index No. ES-A	Commentary
ES-A1	It may be noted that SR ES-A1 is analogous to SR ES-A3 in Addendum B [4-A-12] (the prior version) of the Standard. That version included an option to exclude an initiating event from the internal fire PRA based on the quantitative criteria specified in SR IE-C6 in Part 2 of this Standard. In theory, the SR IE-C6 exclusion might be applied to fire but would be quite difficult to justify, as the analyst would need to consider the cumulative frequency of every fire anywhere in the plant that might lead to the initiating event being excluded (the equivalent to the internal-events initiating-event frequency). To the knowledge of Writing Group 4, the SR IE-C6 exclusion has never been invoked in any internal fire PRA. Therefore, the back reference to this exclusion criterion has been deleted from Part 4 of this Standard as impractical in practice.
ES-A2	In the context of SR ES-A2, it is acceptable to define "equipment" as the system whose failure causes the initiating event; that is, it is not intended that every individual piece of equipment throughout the plant, whose failure might lead to an initiating event, be identified explicitly. Rather, "equipment" might be identified at a higher level (e.g., at the system level). For example, the analyst may choose not to analyze certain balance of plant (BOP) systems at the same level of detail as other plant systems. This decision may, for example, be driven by a lack of cable-routing information for the system in question. In such a case, the BOP system might be treated, in effect, as a "supercomponent" whose failure would lead to an initiating event. Such approaches are intended to be acceptable so long as the uncertainty introduced by such assumptions is acceptable under the requirements of the Internal Fire Risk Quantification technical element. It is understood that equipment extends to the specific piece of equipment itself and any supportive equipment (e.g., power supply, associated actuating instrumentation, and interlocks) needed to perform the intended operation/function of the primary equipment item.
ES-A3	The NEI 00-01 [4-A-2] process for identifying multiple spurious operation (MSO) combinations for deterministic safe-shutdown analysis is one acceptable method for meeting SR ES-A3 if that process is extended to include PRA systems and functions not included in the scope of the safe-shutdown analysis. In some regards, the NEI 00-01 process actually exceeds the scope of analysis specified in companion SRs ES-A4, ES-A5, and ES-A6. In other regards, it may be incomplete relative to the internal fire PRA in that some internal fire PRA systems will likely have been excluded from the scope of a NEI 00-01 analysis.
ES-A4	No commentary provided.
ES-A5	No commentary provided.

Table 4-A.2.2-2 Commentary to Supporting Requirements for HLR-ES-A (Cont'd)

Index No. ES-A	Commentary
ES-A6	For plants adopting NFPA 805 [4-A-3], the Nuclear Safety Capability Assessment is used in lieu of Fire Safe Shutdown/Appendix R Analysis [4-A-9] in the context of SRs ES-A4, ES-A5, and ES-A6. Fire-induced failures leading to interfacing system loss-of-coolant accident or containment bypass are examples of cases where fire-induced failures could contribute to an initiating event that, in turn, leads to core damage and large early release. Random failures do not need to be included in the analyses for this requirement. This requirement also addresses part of HLR-ES-B by addressing operability/functionality of portions of the plant design that may be credited in the internal fire PRA.
ES-A7	Exclusion of equipment or failure modes such as MSOs during the equipment-selection phase can be performed given sufficient justification. For example, NUREG/CR-7150 [4-A-4]identifies certain cable failure modes (or combinations) that are considered incredible, and these modes (or combinations) could be excluded from the internal fire PRA on that basis.

Table 4-A.2.2-3 Commentary to Supporting Requirements for HLR-ES-B

Index No. ES-B	Commentary
ES-B1	No commentary provided.
ES-B2	The NEI 00-01 [4-A-2] process for identifying MSO combinations for deterministic safe-shutdown analysis is one acceptable method for meeting SR ES-B2 if that process is extended to include PRA systems and functions not included in the scope of the safe-shutdown analysis. In some regards, the NEI 00-01 process actually exceeds the scope of analysis specified in companion SR ES-B3. In other regards, it may be incomplete relative to internal fire PRA in that some internal fire PRA systems will likely have been excluded from the scope of a NEI 00-01 analysis.
ES-B3	Exclusion of equipment or failure modes such as MSOs during the equipment-selection phase can be performed given sufficient justification. For example, NUREG/CR-7150 [4-A-4] identifies certain cable failure modes (or combinations) that are considered incredible, and these modes (or combinations) could be excluded from the internal PRA on that basis.

Table 4-A.2.2-4 Commentary to Supporting Requirements for HLR-ES-C

Index No. ES-C	Commentary
ES-C1	Instrumentation needs to be included because of the higher probability of fire-induced indication failure including spurious indications compared with random indication failure. Thus, while random failures of instrumentation may often be ignored in an internal-events PRA, fire-induced instrumentation failure needs to be included in an internal fire PRA. Inclusion of just one fire-induced spurious indication relevant to each operator action being addressed for CC-II is indicative of balancing *(a)* the current state of the art and the resources required to consider almost innumerable combinations of two or more spurious indications against *(b)* the desire to include in the internal fire PRA the associated risk caused by such spurious indications. The intent of CC-I of SR ES-C1 is that the internal fire PRA does not include any identification instrumentation for which a single fire-induced erroneous indication would directly lead the operators intentionally to take an undesirable action impacting one or more of the safety functions modeled in the internal fire PRA. If the analysis includes some identification of this instrumentation, then CC-I requires that the underlying methods and assumptions be described but without an implied judgement regarding adequacy or completeness.
ES-C2	No commentary provided.

Table 4-A.2.2-5 Commentary to Supporting Requirements for HLR-ES-D

Index No. ES-D	Commentary
ES-D1	Documentation does not necessarily imply a separate/unique list of equipment, although producing a separate list of equipment may prove useful. For instance, inclusion in the plant response model for internal fire can be a part of "documenting" the equipment included and its failure modes. The ability to create such a list should exist, especially for peer-review efficiency as well as for performing the internal fire PRA itself.
ES-D2	No commentary provided.

4-A.2.3 Commentary to Internal Fire Cable Selection and Location (CS)

Table 4-A.2.3-1 Commentary to High Level Requirement for Internal Fire Cable Selection and Location (CS)

Designator	Commentary
HLR-CS-A	No commentary provided.
HLR-CS-B	No commentary provided.
HLR-CS-C	No commentary provided.

Table 4-A.2.3-2 Commentary to Supporting Requirements for HLR-CS-A

Index No. CS-A	Commentary
CS-A1	Chapter 3 of NEI-00-01 [4-A-2] provides one acceptable method for performing circuit-failure analysis for circuits identified in the internal fire PRA. The distinction between CC-I and CC-II is the resolution of cable mapping to failure modes (i.e., basic event). In CC-II, specific cables are mapped to the appropriate failure mode based on the circuit analysis for equipment that are risk significant contributors.
CS-A2	The intent of SR CS-A2 is, in part, to provide limits on the scope of instruments to be identified in accordance with the risk importance of operator actions included in the plant response model for internal fire. For example, if the use of a conservative screening HEP shows that an operator action is not a significant contributor, then the analyst may choose not to identify instrumentation and, by implication of SR CS-A1, not to complete cable tracing for such instruments. However, it is intended that, pursuant to this requirement, the instruments relied on by the operator actions will be identified and verified as available to a level of detail commensurate with the risk importance and quantification of the HEPs. In the context of SR ES-A2 (see explanatory note), one acceptable approach to the identification of internal fire PRA equipment is to define "equipment" as the system whose failure causes the initiating event rather than identifying every individual piece of equipment throughout the plant whose failure might lead to an initiating event. In the context of SR CS-A2, if the "supercomponent" approach has been applied, a similar approach to cable selection and location would be expected. That is, in such cases, it is acceptable that individual cables supporting the "supercomponent" system might not be identified and routed in detail but rather simply be associated as a group to various plant locations such that the failure of any support cable would cause failure of the supercomponent/system.
CS-A3	No commentary provided.

Table 4-A.2.3-2 Commentary to Supporting Requirements for HLR-CS-A (Cont'd)

Index No. CS-A	Commentary
CS-A4	The internal fire PRA should strive for completeness in its cable routing information. It is acknowledged, however, that practicality may limit its completeness. If full cable-routing information is not developed, the routing of cables on an exclusionary basis is acceptable; that is, if it can be established (based on the physical features and layout of the plant) that a particular cable (or group of cables) is not routed through a given PAU (or specific location within a PAU), then the internal fire PRA may assume that the excluded cable(s) will not fail for fire scenarios where fire-induced damage is limited to that PAU (or to a specific location within a PAU). A cable terminal end location refers to the location where each end of the cable is terminated at some piece of plant equipment. In some cases, the cable might enter this equipment from the floor below. In these cases, the cable routing information must represent the presence of the cable in the fire area or fire compartment where it is actually terminated. The internal fire PRA may make conservative assumptions regarding cable locations; that is, if the exact routing of a cable (or group of cables) has not been established, the internal fire PRA should assume that those cables fail for any fire scenario that has a damaging effect on any raceway or location where the subject cable might reasonably be located. The determination of where cables might reasonably be located should include the physical layout of the plant equipment and the routing of cables analyzed explicitly using SR CS-A3 from nearby or identical locations. The intent is to allow for the application of conservative assumptions in cases where the specific routing of a cable is not known.

Table 4-A.2.3-3 Commentary to Supporting Requirements for HLR-CS-B

Index No. CS-B	Commentary
CS-B1	No commentary provided.
CS-B2	No commentary provided.

Table 4-A.2.3-4 Commentary to Supporting Requirements for HLR-CS-C

Index No. CS-C	Commentary
CS-C1	No commentary provided.

4-A.2.4 Commentary to Internal Fire Qualitative Screening (QLS)

Table 4-A.2.4-1 Commentary to High Level Requirement for Internal Fire Qualitative Screening (QLS)

Designator	Commentary
HLR-QLS-A	No commentary provided.
HLR-QLS-B	No commentary provided.

Table 4-A.2.4-2 Commentary to Supporting Requirements for HLR-QLS-A

Index No. QLS-A	Commentary
QLS-A1	The use and extent of screening out of PAUs is optional.
QLS-A2	Internal fire PRA practice may involve screening out PAUs if the time available before a required shutdown due to a Technical Specification violation is long. This Standard does not establish a specific time limit but acknowledges the potential validity of this approach. It is expected that analysts will define and specify a basis for their approach if an upper-bound time limit is applied beyond which a shutdown required by the Technical Specifications will not be included as an initiating event.
QLS-A3	It is acceptable for the qualitative screening analysis to retain any PAU for quantitative analysis without a rigorous application of the defined qualitative screening criteria.
QLS-A4	SRs QLS-A1, QLS-A2, and QLS-A3 represent minimum criteria. The intent of SR QLS-A4 is to allow for the application of additional screening criteria. However, if additional criteria are applied, then they must be defined, and a basis for their acceptability must be specified.
QLS-A5	No commentary provided.

Table 4-A.2.4-3 Commentary to Supporting Requirements for HLR-QLS-B

Index No. QLS-B	Commentary
QLS-B1	No commentary provided.
QLS-B2	No commentary provided.

4-A.2.5 Commentary to Internal Fire Plant Response Model (PRM)

Table 4-A.2.5-1 Commentary to High Level Requirement for Internal Fire Plant Response Model (PRM)

Designator	Commentary
HLR-PRM-A	No commentary provided.
HLR-PRM-B	No commentary provided.
HLR-PRM-C	No commentary provided.

Table 4-A.2.5-2 Commentary to Supporting Requirements for HLR-PRM-A

Index No. PRM-A	Commentary
PRM-A1	No commentary provided.
PRM-A2	No commentary provided.
PRM-A3	No commentary provided.

Table 4-A.2.5-3 Commentary to Supporting Requirements for HLR-PRM-B

Index No. PRM-B	Commentary
PRM-B1	No commentary provided.
PRM-B2	The internal-events PRA plant response model is typically used as the starting point for the development of the plant response model for internal fire. All significant deficiencies found in the peer review and any other exceptions for the internal-events PRA should have been properly resolved, and the disposition of these issues should not adversely affect the development of the plant response model for internal fire. The definition of significant deficiency needs to be considered in the context of the regulatory framework (i.e., outside of this Standard and on a country-by-country basis). In the United States, the PRA peer-review guidance indicates that a Finding-level observation impacts the technical adequacy of the PRA and is therefore a significant deficiency. Note that significant in this context is not intended as risk significant.
PRM-B3	No commentary provided.
PRM-B4	No commentary provided.
PRM-B5	No commentary provided.
PRM-B6	No commentary provided.
PRM-B7	No commentary provided.
PRM-B8	No commentary provided.
PRM-B9	No commentary provided.
PRM-B10	Systems and equipment that are included in the internal-events PRA but not selected in the Internal Fire Initiating Events and Equipment Selection element would not be subject to cable selection circuit analysis and cable routing. Any such equipment, potentially vulnerable to fire-induced failure, should be assumed failed in the worst possible failure mode including spurious operation.
PRM-B11	No commentary provided.
PRM-B12	No commentary provided.
PRM-B13	No commentary provided.
PRM-B14	No commentary provided.
PRM-B15	No commentary provided.

Table 4-A.2.5-4 Commentary to Supporting Requirements for HLR-PRM-C

Index No. PRM-C	Commentary
PRM-C1	No commentary provided.
PRM-C2	SR PRM-C2 is intended to address aspects of the plant response model for internal fire that have been modified or are otherwise unique in comparison to those in the internal-events model. Documentation of aspects that have not been modified in the internal fire PRA are expected to be already documented in the internal-events notebooks.
PRM-C3	No commentary provided.

4-A.2.6 COMMENTARY TO INTERNAL FIRE SCENARIO SELECTION AND ANALYSIS (FSS)

Table 4-A.2.6-1 Commentary to High Level Requirement for Internal Fire Scenario Selection and Analysis (FSS)

Designator	Commentary
HLR-FSS-A	No commentary provided.
HLR-FSS-B	No commentary provided.
HLR-FSS-C	No commentary provided.
HLR-FSS-D	No commentary provided.
HLR-FSS-E	No commentary provided.
HLR-FSS-F	No commentary provided.
HLR-FSS-G	No commentary provided.
HLR-FSS-H	No commentary provided.

Table 4-A.2.6-2 Commentary to Supporting Requirements for HLR-FSS-A

Index No. FSS-A	Commentary
FSS-A1	No commentary provided.
FSS-A2	No commentary provided.
FSS-A3	No commentary provided.
FSS-A4	It is expected that the number of individual fire scenarios and the level of detail included in the analysis of each scenario will be commensurate with the relative risk importance of the PAU under analysis. PAUs with small risk contribution may, for example, be characterized based on the conservative analysis of a single bounding fire scenario. The more risk-significant PAUs will likely be characterized by detailed analysis of multiple and/or more specific fire scenarios. In particular, those PAUs that are identified as the significant fire-risk contributors should be characterized by the detailed quantification (see HLR-FSS-C) of one or more fire scenarios that combine specific ignition sources and specific target sets. In internal fire PRA practice, multiple ignition sources may be analyzed by using a single fire scenario (e.g., a bank of several similar electrical panels might be grouped and analyzed with a single fire scenario), provided that the assumed fire-ignition frequency and fire characteristics bound the cumulative contribution of all of the individual ignition sources included under the selected fire scenario.

Table 4-A.2.6-3 Commentary to Supporting Requirements for HLR-FSS-B

Index No. FSS-B	Commentary
FSS-B1	No commentary provided.
FSS-B2	No commentary provided.

Table 4-A.2.6-4 Commentary to Supporting Requirements for HLR-FSS-C

Index No. FSS-C	Commentary
FSS-C1	The intent of CC-II requirements of SR FSS-C1 is that the characterization of the factors that influence the damage that could be caused by ignition sources could be classified in two broad categories: *(a)* sources with a probabilistic representation available and *(b)* sources without a probabilistic representation available. Risk-significant fire-ignition sources for which a probabilistic representation is available should utilize the probabilistic representation. For ignition sources for which no probabilistic representation is available (and for ignition sources that are not risk significant), a simpler representation (e.g., single-point characterization) is acceptable per the second part of SR FSS-C1.
FSS-C2	No commentary provided.
FSS-C3	No commentary provided.
FSS-C4	Conditions and assumptions that could influence whether or not a fire will damage targets include, for example, the distance between fire source and target, the position of the targets relative to the fire source, the damage threshold of the targets, and the mode of fire exposure (e.g., buoyant plume exposure versus radiant heating).
FSS-C5	No commentary provided.
FSS-C6	No commentary provided.
FSS-C7	HLR-FSS-G and its SRs provide for the analysis of fire scenarios impacting adjacent PAUs (the multicompartment fire analysis). SR FSS-C7 is intended, in part, to ensure that a similar analysis is included for cases where barriers exist within a single PAU (i.e., the barriers exist but were not credited during plant partitioning). If the analysis of fire scenarios within a single PAU credits these barriers (e.g., with limiting fire damage, or delaying the spread of fire or the onset of fire damage), then SR FSS-C7 requires an analysis of fire scenarios involving the failure of the credited barrier that is analogous to the multicompartment fire analysis. Such barriers may include passive barriers (e.g., nonrated partition walls, cable wraps, or radiant energy shields) or active barriers (e.g., normally open fire doors or water curtains). NFPA 101 [4-A-11] defines "high hazard" fire sources as "contents that are likely to burn with extreme rapidity or from which explosions are likely." In the context of a nuclear power plant, this would equate to the presence or potential release of large quantities of flammable liquid or hydrogen gas.

Table 4-A.2.6-5 Commentary to Supporting Requirements for HLR-FSS-D

Index No. FSS-D	Commentary
FSS-D1	No commentary provided.
FSS-D2	No commentary provided.
FSS-D3	The intent of SR FSS-D3 is to address parameters used in fire modeling that are not explicitly associated with characterizing the fire-scenario configuration. Examples of these parameters may include thermophysical properties of boundary materials, ambient temperature, etc.
FSS-D4	No commentary provided.
FSS-D5	No commentary provided.
FSS-D6	An example of a statistical fire model would be one where fire-spread behavior within electrical panels or the main control board has been modeled statistically. Another example might be the modeling of fire intensity by using a probability distribution.
FSS-D7	An empirical model, as that term is used here, is a fire model based on experience or observation alone. For example, fire suppression by the manual fire brigade is often based on an empirical relationship derived from a statistical analysis of fire-suppression times reported in past operating experience. A second example is characterizing high-energy arcing faults in electrical switching equipment based on characteristics observed in past events. A third example is the wide range of closed-form empirical correlations documented in sources such as textbooks or engineering handbooks.

Table 4-A.2.6-5 Commentary to Supporting Requirements for HLR-FSS-D (Cont'd)

Index No. FSS-D	Commentary
FSS-D8	Fire scenarios that assume widespread damage (e.g., damage across an entire PAU) will generally include potential smoke damage within the limits of the assumed fire damage (e.g., assuming the loss of all equipment in a PAU given a fire, as might be employed during early stages of a screening analysis).
FSS-D9	A screening-level fire-scenario analysis that assumes widespread fire damage within a PAU would only require confirmation of sources and targets present in the PAU. When determining the scope and details of the walkdown, it is important that the intent of the walkdown be considered. The intent is to identify items that invalidate modeling in the PRA to such an extent that the model does not reasonably represent the as-built, as-operated plant. In keeping with this intent, it is acceptable that conditions that can be justified as not likely to affect the results (i.e., will not change the risk profile or insights) do not need to be validated. As such, and per Inquiry 20-2435 [4-A-13], it is not required that 100% walkdown be performed if adequate justification can be provided that a lesser scope will suffice. Various justifications could be considered valid, but they must show *(a)* that items that could have a significant impact were walked down and *(b)* that those items not walked down could not have a significant impact. The following are examples of possible justifications: *(a) Bounding Risk Impact:* If the importance measure of an item is low, such that even if the item were assumed failed all the time, the PRA results would not meaningfully change. *(b) Adequacy of Documentation:* There is a sufficient weight of evidence, through drawings, photos/videos, analyses, or interviews with knowledgeable plant staff, that the conditions are as assumed in the PRA. *(c) Impact of Possible Discoveries:* Given past experience with the types of deviations typically found during walkdowns, it is not credible or likely that a deviation would be found that could affect the conditions assumed in the PRA to the extent required to meaningfully change the results.
FSS-D10	See commentary for FSS-D9.

Table 4-A.2.6-6 Commentary to Supporting Requirements for HLR-FSS-E

Index No. FSS-E	Commentary
FSS-E1	Typical internal fire PRA practice involves the application of a nonsuppression probability, that is, the probability that suppression efforts fail to suppress the fire before the onset of the postulated equipment/cable damage. Thus, the nonsuppression probability estimate includes an assessment of effectiveness (including the relative timing of fire damage versus detection/suppression and fire brigade performance), discussed in SR FSS-E2, as well as an overall assessment of system unavailability. The intent of CC-II requirements of SR FSS-E1 is to require increasing levels of plant specificity in assessing system unavailability. The applicable codes and standards will generally be the relevant NFPA code(s) of record. The intent for CC-II is to additionally require a review of plant records to determine whether the generic unavailability estimate is consistent with actual system unavailability. Outlier experience would be any experience indicating that the actual system is unavailable more frequently than would be indicated by the generic values. The total system unavailability is intended to represent functional performance of the system; for example, a detector system may function even though one or more individual detectors are out of service or fail. Also note that total system unavailability includes unreliability.
FSS-E2	No commentary provided.
FSS-E3	No commentary provided.
FSS-E4	The statistical treatment of manual fire suppression is typically complementary to the events included when fire frequency is estimated; as a result, the two factors are typically highly dependent. The use of the ignition frequency and fire suppression values published in EPRI 3002002936/NUREG-2169/ [4-A-5] is one acceptable method to meet this SR; that is, the analyses performed in accordance with the EPRI report meet the requirements of this SR.

Table 4-A.2.6-7 Commentary to Supporting Requirements for HLR-FSS-F

Index No. FSS-F	Commentary
FSS-F1	The prototypical fire scenario leading to failure of structural steel would be catastrophic failure of the turbine itself (e.g., a blade ejection event) and an ensuing lube-oil fire. For the lube-oil fire, the possibility of effects of pooling, the flaming oil traversing multiple levels, and spraying from continued lube-oil pump operation should be included. Additional examples would include scenarios involving other high-hazard fire sources present in the relevant PAUs (e.g., oil storage tanks, hydrogen storage tanks and piping, mineral oil-filled transformers).
FSS-F2	No commentary provided.

Table 4-A.2.6-8 Commentary to Supporting Requirements for HLR-FSS-G

Index No. FSS-G	Commentary
FSS-G1	In applying requirements SRs FSS-C1, FSS-C2, FSS-C3, FSS-C4, FSS-C5, FSS-C6, and FSS-C7, additional phenomena associated with multicompartment fire scenarios, beyond those associated with scenarios of single PAUs, may be addressed. For example, the modeling of hot gas flow through openings and ducts from the PAU of fire origin may be necessary.
FSS-G2	No commentary provided.
FSS-G3	No commentary provided.
FSS-G4	Passive fire barrier features that may have been credited in plant partitioning or scenario analysis include items such as walls, normally closed fire doors, penetration seals, and other similar features that require no action (manual or automatic) to perform their intended function. This requirement would apply to all passive fire barrier elements credited in the internal fire PRA, including the plant partitioning, as well as in the fire-scenario selection and analysis. The fire-resistance rating of passive fire barrier features is typically established in accordance with the ASTM E 119-10b [4-A-6] standard and/or other similar, related, or subsidiary standards.
FSS-G5	No commentary provided.
FSS-G6	Active fire barrier elements include items such as normally open fire doors, dampers, water curtains, and other similar items that require that some action (manual or automatic) occur for the element to perform its intended function.
FSS-G7	No commentary provided.
FSS-G8	No commentary provided.

Table 4-A.2.6-9 Commentary to Supporting Requirements for HLR-FSS-H

Index No. FSS-H	Commentary
FSS-H1	No commentary provided.
FSS-H2	No commentary provided.
FSS-H3	No commentary provided.

4-A.2.7 Commentary to Internal Fire Ignition Frequency (IGN)

Table 4-A.2.7-1 Commentary to High Level Requirement for Internal Fire Ignition Frequency (IGN)

Designator	Commentary
HLR-IGN-A	No commentary provided.
HLR-IGN-B	No commentary provided.

Table 4-A.2.7-2 Commentary to Supporting Requirements for HLR-IGN-A

Index No. IGN-A	Commentary
IGN-A1	No commentary provided.
IGN-A2	No commentary provided.
IGN-A3	No commentary provided.
IGN-A4	Outlier experience includes cases where the plant has experienced more fires of any given type than would be expected, given the generic industry experience, or where the plant has experienced a type of fire that is a potential risk contributor but is not included in the generic event database.
IGN-A5	The analysis required by SR IGN-A5 addresses the fraction of the year that the plant is in at-power operational state. For further discussion, see the explanatory note for SR IE-C5 in Part 2.
IGN-A6	No commentary provided.
IGN-A7	An example of a "plantwide consistent methodology" would be one in which, if equipment count were chosen as the approach for determining PAU apportioning factors, counting rules should be established and applied consistently throughout all the PAUs in the plant and should preserve the plantwide fire frequency.
IGN-A8	The analysis must include all potential ignitions sources, both fixed and transient.
IGN-A9	No commentary provided.
IGN-A10	No commentary provided.

Table 4-A.2.7-3 Commentary to Supporting Requirements for HLR-IGN-B

Index No. IGN-B	Commentary
IGN-B1	No commentary provided.
IGN-B2	No commentary provided.

4-A.2.8 COMMENTARY TO INTERNAL FIRE CIRCUIT FAILURE ANALYSIS (CF)

Table 4-A.2.8-1 Commentary to High Level Requirement for Internal Fire Circuit Failure Analysis (CF)

Designator	Commentary
HLR-CF-A	No commentary provided.
HLR-CF-B	No commentary provided.

Table 4-A.2.8-2 Commentary to Supporting Requirements for HLR-CF-A

Index No. CF-A	Commentary
CF-A1	No commentary provided.
CF-A2	No commentary provided.
CF-A3	No commentary provided.

Table 4-A.2.8-3 Commentary to Supporting Requirements for HLR-CF-B

Index No. CF-B	Commentary
CF-B1	No commentary provided.
CF-B2	No commentary provided.

4-A.2.9 Commentary to Internal Fire Human Reliability Analysis (FHR)

Table 4-A.2.9-1 Commentary to High Level Requirement for Internal Fire Human Reliability Analysis (FHR)

Designator	Commentary
HLR-FHR-A	No commentary provided.
HLR-FHR-B	No commentary provided.
HLR-FHR-C	No commentary provided.
HLR-FHR-D	No commentary provided.
HLR-FHR-E	No commentary provided.

Table 4-A.2.9-2 Commentary to Supporting Requirements for HLR-FHR-A

Index No. FHR-A	Commentary
FHR-A1	The requirements of the Internal Fire Plant Response Model technical element address HFEs carried over from the internal-events analysis. SR FHR-A1 addresses new HFEs that are unique to the fire analysis. The intent of CC-I requirements of SR FHR-A1 is that the plant response model for internal fire does not include any identification any new, undesired operator action that could result from fire-induced spurious indications resulting from failure of a single instrument. If the analysis includes some identification of these undesired actions, then CC-I requires that the underlying methods and assumptions be described but without an implied judgement regarding adequacy or completeness.
FHR-A2	No commentary provided.

Table 4-A.2.9-3 Commentary to Supporting Requirements for HLR-FHR-B

Index No. FHR-B	Commentary
FHR-B1	No commentary provided.
FHR-B2	HFEs related to actions previously modeled in an analysis such as the internal-events PRA may have to be modified because the fire may change the scenario characteristics such as timing, cues, or specific actions that would have to be taken (e.g., due to fire-induced circuit failures that affect the manner in which certain components may be operated). These changes would therefore require alteration of a previously defined HFE to fit the applicable fire situation in the internal fire PRA. One example of an undesired operator action would be shutting down a pump because of a spurious pump high-temperature alarm.

Table 4-A.2.9-4 Commentary to Supporting Requirements for HLR-FHR-C

Index No. FHR-C	Commentary
FHR-C1	One acceptable method for meeting this requirement is stated in EPRI 1023001 NUREG-1921 [4-A-7] including its definition of detailed analysis versus screening/scoping methods.

Table 4-A.2.9-5 Commentary to Supporting Requirements for HLR-FHR-D

Index No. FHR-D	Commentary
FHR-D1	An example of a fire-related effect that must be analyzed carefully in identifying and evaluating recovery actions is the potential for a circuit failure that could both defeat automatic operation of a valve and prevent remote manual operation (see Information Notice 92-18, [4-A-8]).
FHR-D2	No commentary provided.

Table 4-2.9-6 Commentary to Supporting Requirements for HLR-FHR-E

Index No. FHR-E	Commentary
FHR-E1	No commentary provided.
FHR-E2	No commentary provided.

4-A.2.10 Commentary to Internal Fire Risk Quantification (FQ)

Table 4-A.2.10-1 Commentary to High Level Requirement for Internal Fire Risk Quantification (FQ)

Designator	Commentary
HLR-FQ-A	No commentary provided.
HLR-FQ-B	No commentary provided.
HLR-FQ-C	No commentary provided.
HLR-FQ-D	No commentary provided.
HLR-FQ-E	No commentary provided.
HLR-FQ-F	No commentary provided.
HLR-FQ-G	No commentary provided.

Table 4-A.2.10-2 Commentary to Supporting Requirements for HLR-FQ-A

Index No. FQ-A	Commentary
FQ-A1	Prior versions of this Standard [4-A-10] included a technical element called Quantitative Screening (QNS). SR FQ-A1 in this Standard embodies the requirements of what was HLR-QNS-A and its SRs in the prior versions.
FQ-A2 FQ-A3	In some cases, a given fire scenario could lead to more than one initiating event. For example, in the case of a pump control cable failure, spurious operation of the pump might imply one initiating event, whereas a loss of function failure might imply a different initiating event. For screening purposes, the selection of the most conservative (i.e., the most challenging from the CDF and LERF perspectives) initiating event might be assumed with a conditional probability of 1.0 for the corresponding pump failure mode. Quantification might also consider both initiators with a split fraction applied to represent each pump-failure mode. The intent of SR FQ-A2 is to ensure that the selected initiating event (or events) encompasses the risk contribution from all applicable initiating events. When quantifying fire scenarios based on an internal-events initiating-event sequence, there may be a difference in Success Criteria, timing of human actions, and other elements of the PRA model for a fire-induced system failure that causes a reactor trip and the same failure if it occurs after a reactor trip. If, for example, the internal fire PRA model employs a general transient as the initiating event, with all of the fire impacts included as failures subsequent to that trip, then to meet the intent of SR FQ-A2, it would be appropriate to ensure that any differences with respect to selecting a more specific initiating event are negligible.
FQ-A4	No commentary provided.
FQ-A5	No commentary provided.

Table 4-A.2.10-3 Commentary to Supporting Requirements for HLR-FQ-B

Index No. FQ-B	Commentary
FQ-B1	No commentary provided.

Table 4-A.2.10-4 Commentary to Supporting Requirements for HLR-FQ-C

Index No. FQ-C	Commentary
FQ-C1	No commentary provided.

Table 4-A.2.10-5 Commentary to Supporting Requirements for HLR-FQ-D

Index No. FQ-D	Commentary
FQ-D1	Prior versions of this Standard [4-A-10] included a technical element called Quantitative Screening (QNS). SR FQ-D1 in this Standard embodies the requirements of HLR-QNS-B and its SRs in the prior versions.
FQ-D2	No commentary provided.

Table 4-A.2.10-6 Commentary to Supporting Requirements for HLR-FQ-E

Index No. FQ-E	Commentary
FQ-E1	There is no requirement for a comparison of internal fire PRA results for similar plants under this SR FQ-E1, due to lack of publicly available internal fire PRA results. Additionally, small differences in geometry, plant layout, and the Fire Safe Shutdown Procedures may result in significant differences in risk that may be difficult to understand without detailed internal fire PRA results from plants being compared.

Table 4-A.2.10-7 Commentary to Supporting Requirements for HLR-FQ-F

Index No. FQ-F	Commentary
FQ-F1	In prior versions of this Standard [4-A-10], Part 4 included a technical element called Uncertainty and Sensitivity Analysis. In this Standard, the Uncertainty and Sensitivity Analysis technical element has been eliminated and the requirements for uncertainty have been incorporated into the Internal Fire Risk Quantification technical element via HLR-FQ-F.
FQ-F2	No commentary provided.

Table 4-A.2.10-8 Commentary to Supporting Requirements for HLR-FQ-G

Index No. FQ-G	Commentary
FQ-G1	No commentary provided.
FQ-G2	No commentary provided.
FQ-G3	No commentary provided.

4-A.3 REFERENCES

The following is a list of publications referenced in this Appendix.

[4-A-1] EPRI TR-1011989 and NUREG/CR-6850, "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities." A joint Electric Power Research Institute (EPRI) and U.S. Nuclear Regulatory Commission (NRC) publication. September 2005 (a report in two volumes). NRC has endorsed the original 2001 version of NFPA-805 but not the 2006 revision. EPRI, 3412 Hillview Avenue, Palo Alto, CA 94303, and NRC, One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[4-A-2] NEI 00-01, Rev. 4, "Guidance for Post-Fire Safe Shutdown Analysis," December 2019; Nuclear Energy Institute (NEI), 1201 F St., NW, Suite 1100, Washington, DC 20004-1218

[4-A-3] NFPA Standard 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants," 2001; National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169

[4-A-4] NUREG/CR-7150, Vols. 1–3; BNL-NUREG-98204-2012, Vols. 1–3; and EPRI 1026424, Vol. 1, EPRI 3002001989, Vol. 2, and EPRI 3002009214, Vol. 3; "Joint Assessment of Cable Damage and Quantification of Effects from Fire (JACQUE-FIRE): Final Report." A joint U.S. Nuclear Regulatory Commission (NRC), Brookhaven National Laboratory (BNL), and Electric Power Research Institute (ERPI) publication. 2012, 2014, 2017 respectively; NRC, One White Flint North, 11555 Rockville Pike, Rockville, MD 20852, and EPRI, 3412 Hillview Avenue, Palo Alto, CA 94303

[4-A-5] EPRI 3002002936 and NUREG-2169, "Nuclear Power Plant Fire Ignition Frequency and Non-Suppression Probability Estimation Using the Updated Fire Events Database: United States Fire Event Experience Through 2009," January 2015; Electric Power Research Institute (EPRI), 3412 Hillview Avenue, Palo Alto, CA 94303, and U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[4-A-6] ASTM Standard E119 10b, "Standard Test Methods for Fire Tests of Building Construction and Materials," October 2010; American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428

[4-A-7] EPRI 1023001 and NUREG-1921, "NRC-RES Fire Human Reliability Analysis Guidelines," May 2012; Electric Power Research Institute (EPRI), 3412 Hillview Avenue, Palo Alto, CA 94303, and U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[4-A-8] Information Notice No. 92-18, "Potential for Loss of Remote Shutdown Capability During a Control Room Fire," February 28, 1992; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[4-A-9] U.S. Nuclear Regulatory Commission (NRC), 10 CFR 50.48, Appendix R to Part 50, "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979"

[4-A-10] ASME/ANS RA-Sa-2009, "Addenda to ASME/ANS RA-S-2008 Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications," American Society of Mechanical Engineers (ASME) and American Nuclear Society (ANS), 2009; ASME, Two Park Avenue, New York, NY 10016-5990

[4-A-11] NFPA Standard 101, "Life Safety Code," 2015; National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169

[4-A-12] ASME/ANS RA-Sb-2013 (R2019), "Addenda to ASME/ANS RA-S-2008 Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications," American Society of Mechanical Engineers (ASME) and American Nuclear Society (ANS), 2013; ASME, Two Park Avenue, New York, NY 10016-5990

[4-A-13] JCNRM Inquiry Record 20-2435, The American Society of Mechanical Engineers (ASME) and the American Nuclear Society (ANS), Joint Committee Nuclear Risk Management (JCNRM) Inquiries and Interpretations, ASME, website link: https://cstools.asme.org/csconnect/CommitteePages.cfm?Committee=100186782&Action=40886

PART 5
REQUIREMENTS FOR SEISMIC EVENTS FOR AT-POWER PRA

Section 5-1
Overview of Seismic PRA Requirements At-Power

5-1.1 PRA SCOPE

This Part states technical requirements for a Level 1 core damage frequency (CDF) analysis and a large early release frequency (LERF) analysis of seismic events while at-power.

5-1.2 COORDINATION WITH OTHER PARTS OF THIS STANDARD

This Part is intended to be used with other Parts of this Standard (Part 1, Part 2, Part 3, Part 4, and Part 8). An internal events for at-power operation PRA developed in accordance with Part 2 is the starting point for the development of the seismic-induced accident-sequence model.

(The text presented in **blue font** in this Standard comprise hyperlinks to enable efficient access to referenced sections and elements, requirements, notes, references, etc.)

Section 5-2
Seismic At-Power Technical Elements and Requirements

The technical requirements for seismic PRA (SPRA) have been developed based on a wealth of experience of more than 30 years. This experience includes a large number of full-scope SPRAs for nuclear power plants and a large number of methodology guidance documents and methodology reviews. The major PRA technical elements of an SPRA are

(a) Seismic Hazard Analysis (SHA)
(b) Seismic Fragility Analysis (SFR)
(c) Seismic Plant Response Analysis (SPR)

The technical requirements for each of these are given in the following subsections.

SPRA is an integrated activity requiring close interactions among specialists from different fields (e.g., hazard analysis, systems analysis, and fragility analysis). For this reason, it is important that all members of the SPRA team be cognizant of all of the Supporting Requirements (SRs) in this Part, not just those in their area of expertise, and understand the interactions required between the elements. This understanding of this Standard will promote consistency among similar PRAs and risk-informed applications and will also promote reasonableness in the numerical results and risk insights.

5-2.1 SEISMIC HAZARD ANALYSIS (SHA)

5-2.1.1 Objectives

The objectives of the Seismic Hazard Analysis are to

(a) perform site-specific Seismic Hazard Analysis to evaluate the range of seismic vibratory ground motion of interest to the SPRA
(b) identify secondary hazards (e.g., landslides, soil liquefaction, soil settlement, and earthquake-induced external flooding) and develop hazard analysis for those that do not screen from further consideration
(c) identify, evaluate, and quantify associated uncertainties
(d) document the Seismic Hazard Analysis to provide traceability of the work

The requirements described in Section 5-2.1 address these objectives in detail. Seismic Hazard Analysis encompasses all aspects of hazard analysis and includes assessment of vibratory ground motions, as well as of secondary hazards induced by the ground motions, the potential for fault rupture, and site response. Vibratory ground motions include both horizontal and vertical components. A probabilistic seismic hazard analysis (PSHA) is used to assess horizontal ground motions at the site. Site response analyses must also be addressed in Seismic Hazard Analysis for nonrock sites and may be directly incorporated into the PSHA analysis.

This Part covers ground motions that arise from natural tectonic processes and does not include nonstationary seismicity induced or triggered by human activities (e.g., hydraulic fracturing and wastewater injection). Induced seismicity should be evaluated and, as appropriate, screened out using the requirements in Part 6 or a hazard model developed using the requirements in Part 9.

The aforementioned objectives form the basis for the nine High Level Requirements (HLRs) for Seismic Hazard Analysis stated in Table 5-2.1-1.

Table 5-2.1-1 High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Seismic Hazard Analysis (SHA)

Designator	Requirement
HLR-SHA-A	The basis for the calculation of the frequencies of exceeding different levels of seismic horizontal vibratory ground motion at the site shall be a site-specific PSHA that represents the center, body, and range of the technically defensible interpretations.
HLR-SHA-B	Inputs to the PSHA shall include characterization of uncertainty and shall be based on current geological, seismological, and geophysical data; local site topography; and surficial geologic and geotechnical site properties. A catalog of historical, instrumental, and paleoseismic information shall be compiled. Available models and methods shall be compiled.
HLR-SHA-C	To assess the frequency of exceedance of seismic ground motion levels in the site region, the PSHA shall examine all credible sources of potentially damaging earthquakes. Uncertainties in the seismic source characterization shall be identified and addressed.
HLR-SHA-D	The PSHA shall include a ground motion characterization (GMC) model that determines the range of seismic horizontal vibratory ground motion that can occur at a site given the occurrence of an earthquake at a specific location and of a certain type (e.g., strike slip, normal, reverse) and magnitude. Uncertainties in characterizing the ground motion propagation shall be identified and included.
HLR-SHA-E	The Seismic Hazard Analysis shall include the effects of local site response. Uncertainties in characterizing the local site response analysis shall be identified and included.
HLR-SHA-F	Aleatory and epistemic uncertainty in each step of the hazard analysis shall be propagated in the final quantification of hazard estimates for the site.
HLR-SHA-G	For further use in the Seismic Fragility Analysis, the spectral shape shall be based on site-specific evaluation that considers or incorporates the results of the hazard analysis.
HLR-SHA-H	An evaluation shall be performed to assess whether, in addition to the vibratory ground motion, other seismic hazards need to be included in the SPRA.
HLR-SHA-I	The documentation of the hazard analysis shall provide traceability of the work.

Table 5-2.1-2 Supporting Requirements for HLR-SHA-A

The basis for the calculation of the frequencies of exceeding different levels of seismic horizontal vibratory ground motion at the site shall be a site-specific PSHA that represents the center, body, and range of the technically defensible interpretations (HLR-SHA-A).

Index No. SHA-A	Capability Category I	Capability Category II
SHA-A1	USE a defined process to develop the PSHA model to ensure that the PSHA represents the center, body, and range of the technically defensible interpretations in accordance with the requirement in Section 1-4.	
SHA-A2	USE the spectral acceleration (Sa), the average Sa over a selected band of frequencies, or the peak ground acceleration as the parameter to characterize both hazards and fragilities.	
SHA-A3	ENSURE that the ground motion parameter(s) and range of frequencies selected for the PSHA are consistent with the ground motion parameter(s) needed for subsequent fragility and plant-response analysis (see SR SPR-E1).	
SHA-A4	In developing the PSHA results for use in accident-sequence quantification (whether characterized by Sa, peak ground acceleration, or both), EXTEND the range of ground motion levels considered to be large enough values (consistent with available earth science data and interpretations) such that the truncation does not distort final numerical results (e.g., on parameters such as CDF and LERF) and the delineation and ranking of seismic-induced sequences are not distorted.	
SHA-A5	JUSTIFY the specified lower-bound magnitude for use in the hazard analysis, such that earthquakes of magnitudes less than this value are not expected to cause significant damage to the engineered structures or equipment.	
SHA-A6	JUSTIFY the specified number of standard deviations from the median of the ground motion value (e.g., Sa) to be included in the analysis of the Ground Motion Prediction Equation (GMPE) such that aleatory variability in the ground motion prediction is properly modeled.	

Table 5-2.1-3 Supporting Requirements for HLR-SHA-B

Inputs to the PSHA shall include characterization of uncertainty and shall be based on current geological, seismological, and geophysical data; local site topography; and surficial geologic and geotechnical site properties. A catalog of historical, instrumental, and paleoseismic information shall be compiled. Available models and methods shall be compiled (HLR-SHA-B).

Index No. SHA-B	Capability Category I	Capability Category II
SHA-B1	In performing the PSHA, USE current geological, seismological, geophysical, and geotechnical data that are used by subject matter experts/analysts to develop interpretations and inputs to the PSHA.	
SHA-B2	ENSURE that the size of the region to be investigated and the data and information used are adequate to characterize all credible seismic sources that may be significant contributors to the seismic hazard at the site and the uncertainties associated with the hazard results.	
SHA-B3	ENSURE that the data and information are sufficient to characterize attributes significant for modeling both regional propagation of ground motions and local site effects including their associated uncertainties.	
SHA-B4	ENSURE that new data, models, methods, and interpretations that were unknown when the existing models were developed or not previously used and that could affect an existing PSHA are identified and compiled.	
SHA-B5	USE a compiled catalog of historically reported earthquakes, instrumentally recorded earthquakes, and earthquakes identified through geological investigations in performing the PSHA.	

Table 5-2.1-4 Supporting Requirements for HLR-SHA-C

To assess the frequency of exceedance of seismic ground motion levels in the site region, the PSHA shall examine all credible sources of potentially damaging earthquakes. Uncertainties in the seismic source characterization shall be identified and addressed (HLR-SHA-C).

Index No. SHA-C	Capability Category I	Capability Category II
SHA-C1	In the PSHA, IDENTIFY sources of earthquakes that have the potential to be significant contributors to the seismic hazard at the site.	
SHA-C2	USE a structured approach to characterize seismic sources using the information compiled in accordance with HLR-SHA-A and HLR-SHA-B.	
SHA-C3	USE a structured approach to identify and include sources of uncertainty in the modeling of the seismic sources.	
SHA-C4	If an existing seismic source model is used, DEMONSTRATE that new seismic sources, models, and methods unknown when the existing models were developed or not previously used are included in the center, body, and range of the existing model and do not challenge the technical validity of the existing model.	
SHA-C5	If an existing seismic source model is updated for use in the PSHA, JUSTIFY the level and method of analysis used in the update of the model.	

Table 5-2.1-5 Supporting Requirements for HLR-SHA-D

The PSHA shall include a GMC model that determines the range of seismic horizontal vibratory ground motion that can occur at a site given the occurrence of an earthquake at a specific location and of a certain type (e.g., strike slip, normal, reverse) and magnitude. Uncertainties in characterizing the ground motion propagation shall be identified and included (HLR-SHA-D).

Index No. SHA-D	Capability Category I	Capability Category II
SHA-D1	In the GMC model that determines the range of seismic vibratory ground motion that can occur at a site, INCLUDE *(a)* credible mechanisms governing estimates of vibratory ground motion that can occur at a site *(b)* a review of available historical and instrumental seismicity data (including strong motion data) to assess and calibrate the model *(c)* criteria for selection of (existing and/or newly developed) GMPEs for the ground motion estimates *(d)* reference soil or rock horizon (defined by shear wave velocity, density, and damping values)	
SHA-D2	ENSURE that the process used to characterize the ground motion or the other elements of the ground motion analysis is compatible with the level of analysis discussed in HLR-SHA-A.	
SHA-D3	ENSURE that uncertainties are included in the model such that the aggregate of predicted ground motion captures the range of ground motions that can occur at a site in accordance with the level of analysis identified for HLR-SHA-A and the data and information identified in HLR-SHA-B.	
SHA-D4	If existing ground motion models are used, DEMONSTRATE that available new data, models, methods, and information unknown when the existing models were developed or not previously used would not significantly distort the PSHA ground motion results or INCLUDE new ground motion data, models, methods, and information in the update of the PSHA.	

Table 5-2.1-6 Supporting Requirements for HLR-SHA-E

The Seismic Hazard Analysis shall include the effects of local site response. Uncertainties in characterizing the local site response analysis shall be identified and included (HLR-SHA-E).

Index No. SHA-E	Capability Category I	Capability Category II
SHA-E1	In the Seismic Hazard Analysis, INCLUDE the effects of site topography, surficial geologic deposits, and site geotechnical properties on ground motions at the site.	
SHA-E2	INCLUDE uncertainties in the local site response analysis.	
SHA-E3	JUSTIFY the approach used to incorporate the site response analysis into the hazard analysis (e.g., sources of soils and rock material properties used in the analysis, uncertainties in site characterization and material properties, data to identify the depth to bedrock, appropriateness of one- two- or three-dimensional analysis in relation to the site stratigraphy).	

Table 5-2.1-7 Supporting Requirements for HLR-SHA-F

Aleatory and epistemic uncertainty in each step of the hazard analysis shall be propagated in the final quantification of hazard estimates for the site (HLR-SHA-F).

Index No. SHA-F	Capability Category I	Capability Category II
SHA-F1	CALCULATE the following results as a part of the hazard quantification process, compatible with the level of analysis determined in HLR-SHA-A: *(a)* fractile and mean hazard curves for each ground motion parameter included in the PSHA *(b)* uniform hazard response spectra at hazard exceedance frequencies of interest *(c)* magnitude-distance deaggregation for the mean hazard *(d)* seismic source deaggregation *(e)* ground motion model deaggregation *(f)* mean magnitude and distance	
SHA-F2	CALCULATE seismic-hazard results that are required as input to the SPRA quantification (e.g., calculation of seismic core damage frequency (SCDF) and seismic large early release frequency (SLERF) per HLR-SPR-E), including results from the PSHA, analysis of vertical motions, and analysis of secondary seismic hazards.	
SHA-F3	By performing sensitivity studies, IDENTIFY the sources of modeling uncertainty in the PSHA that may distort the hazard results.	
SHA-F4	By performing sensitivity studies, IDENTIFY the sources of epistemic uncertainty in the assessment of vertical motions, the site response analysis, and the evaluation of secondary hazards performed in SR SHA-H3 that may distort the quantification results as discussed in SR SPR-E8.	

Table 5-2.1-8 Supporting Requirements for HLR-SHA-G

For further use in the Seismic Fragility Analysis, the spectral shape shall be based on site-specific evaluation that considers or incorporates the results of the hazard analysis (HLR-SHA-G).

Index No. SHA-G	Capability Category I	Capability Category II
SHA-G1	ENSURE that the horizontal response spectral shape determined in the Seismic Hazard Analysis is based on site-specific evaluations and uses or bounds the characteristic spectral shapes associated with the mean magnitude and distance pairs determined in the Seismic Hazard Analysis for the significant ground motion levels.	
SHA-G2	DEMONSTRATE that the methods for determining vertical spectra are appropriate given the current state of knowledge.	

Table 5-2.1-9 Supporting Requirements for HLR-SHA-H

An evaluation shall be performed to assess whether, in addition to the vibratory ground motion, other seismic hazards need to be included in the SPRA (HLR-SHA-H).

Index No. SHA-H	Capability Category I	Capability Category II
SHA-H1	IDENTIFY fault displacement and secondary seismic hazards associated with vibratory ground motion for the site (e.g., landslides, soil liquefaction, soil settlement, and earthquake-induced external flooding).	
SHA-H2	JUSTIFY the screening out of seismic hazards identified by SR SHA-H1 (e.g., based on demonstrably conservative assessments) using SCR-2 or SCR-3 from Table 1-1.8-1.	
SHA-H3	For non-flooding-related seismic hazards that are not screened out in SR SHA-H2, CALCULATE the frequency of levels of hazard parameters used to define the fragility for failure mechanisms of seismic equipment list (SEL) items that may be impacted.	
SHA-H4	For earthquake-induced external flooding hazards that are not screened out in SR SHA-H2, SATISFY the applicable requirements of HLR-XFHA-A, HLR-XFHA-B, HLR-XFHA-C, HLR-XFHA-D, HLR-XFHA-E, HLR-XFHA-F, and HLR-XFHA-G in Part 8 in calculating the frequency of hazard parameters necessary to define the fragility for failure mechanisms of SEL items that may be impacted.	

Table 5-2.1-10 Supporting Requirements for HLR-SHA-I

The documentation of the hazard analysis shall provide traceability of the work (HLR-SHA-I).

Index No. SHA-I	Capability Category I	Capability Category II
SHA-I1	DOCUMENT the process used in the Seismic Hazard Analysis specifying what is used as input, the applied methods, and the results. Address the following and other details needed to fully document how the set of SRs is satisfied: *(a)* the data and information that form the basis and input for the evaluations carried out to develop the PSHA inputs, including the seismic source characterization, the GMC, and the site response *(b)* the PSHA model structure *(c)* the structured processes used to ensure that the center, body, and range of technically defensible interpretations have been considered *(d)* the specific methods used for source characterization, GMC, and local site response analysis *(e)* the scientific interpretations that are the basis for the PSHA inputs and results *(f)* the process to ensure that an existing PSHA, if used, meets the requirements herein *(g)* the methods for determining vertical spectra *(h)* the set of secondary seismic hazards identified in SR SHA-H1 *(i)* the methods for screening and incorporating secondary seismic hazards *(j)* the results of the hazard analyses consistent with HLR-SHA-F	
SHA-I2	DOCUMENT the sources of model uncertainty within the Seismic Hazard Analysis hazard models, related assumptions, and reasonable alternatives associated with the Seismic Hazard Analysis identified in SR SHA-F3 and SR SHA-F4.	

5-2.2 SEISMIC FRAGILITY ANALYSIS (SFR)

The seismic fragility of a structure, system, or component (SSC) is defined as the conditional probability of its failure at a given value of a seismic motion parameter (e.g., Sa, average Sa over a selected band of frequencies, or peak ground acceleration).

5-2.2.1 Objectives

The objectives of the Seismic Fragility Analysis are to

(a) develop seismic-fragility information for all the SSCs in the model

(b) ensure fragilities for the risk-significant contributors to SCDF and/or SLERF are realistic and plant specific and incorporate the data and findings of walkdown(s) in the plant

(c) identify, evaluate, and quantify associated uncertainties

(d) document the Seismic Fragility Analysis to provide traceability of the work

The aforementioned objectives form the basis for the six HLRs for fragility analysis stated in Table 5-2.2-1.

Table 5-2.2-1 High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Seismic Fragility Analysis (SFR)

Designator	Requirement
HLR-SFR-A	The Seismic Fragility Analysis shall address seismic fragilities of SSCs whose failure may contribute to core damage or large early release.
HLR-SFR-B	The Seismic Fragility Analysis shall be based on a seismic response that the SSCs experience at failure.
HLR-SFR-C	The basis and methodologies used to establish the fragility threshold for SSCs shall be defined.
HLR-SFR-D	The Seismic Fragility Analysis shall incorporate the data and findings of walkdown(s) of the plant to establish or confirm as-built, as-operated conditions.
HLR-SFR-E	The Seismic Fragility Analysis shall be performed for relevant failure mechanisms affecting the failure modes modeled in the plant-response analysis.
HLR-SFR-F	The documentation of the Seismic Fragility Analysis shall provide traceability of the work.

Table 5-2.2-2 Supporting Requirements for HLR-SFR-A

The Seismic Fragility Analysis shall address seismic fragilities of SSCs whose failure may contribute to core damage or large early release (HLR-SFR-A).

Index No. SFR-A	Capability Category I	Capability Category II
SFR-A1	INCLUDE in the scope of the fragility analysis those SSCs and associated failure modes identified by the plant-response analysis (see HLR-SPR-C).	
SFR-A2	INCLUDE information relevant to modeling of fragility correlation of SSCs and its basis (e.g., similarity of component construction, location and orientation, and in-structure seismic demand) to support SR SPR-B4.	

Table 5-2.2-3 Supporting Requirements for HLR-SFR-B

The Seismic Fragility Analysis shall be based on a seismic response that the SSCs experience at failure (HLR-SFR-B).

Index No. SFR-B	Capability Category I	Capability Category II
SFR-B1	ESTIMATE seismic response for use in fragility evaluation of the SSCs using the earthquake response spectra shape(s) from HLR-SHA-G in three orthogonal directions and JUSTIFY that any approximations are conservative and appropriate for the plant.	CALCULATE realistic seismic response for use in fragility evaluation of the SSCs using the earthquake response spectra shape(s) from HLR-SHA-G in three orthogonal directions and JUSTIFY that any approximations are appropriate for the plant and do not significantly distort the overall SPRA results (e.g., provide a basis for scaling response from one ground motion level to another).
SFR-B2	If scaling of existing response analysis is used, JUSTIFY it based on the adequacy of structural models, foundation characteristics, and similarity of input ground motion.	
SFR-B3	USE realistic mathematical structural models to represent the three-dimensional dynamic characteristics of the building structures (e.g., consider stiffness, mass, damping, stress state, directional coupling, rotational inertia, center of mass, discretization, modal frequency response, torsional effects, diaphragm flexibility, structural coupling) for seismic response calculations.	
SFR-B4	If median-centered response analysis is performed, ESTIMATE the median response (i.e., structural loads and floor response spectra) and variability in the response.	If median-centered response analysis is performed, CALCULATE the median response (i.e., structural loads and floor response spectra) and variability in the response.
SFR-B5	If soil-structure interaction (SSI) effects are considered, ESTIMATE median-centered SSI response and associated uncertainty based on soil properties consistent with site conditions.	If SSI effects are significant to structural response, CALCULATE median-centered SSI response and associated uncertainty using site-specific, strain-compatible soil properties
SFR-B6	If probabilistic response analysis is performed to calculate structural loads and floor response spectra, ENSURE that the number of simulations (e.g., Monte Carlo simulation or Latin Hypercube Sampling) is large enough to calculate stable responses.	

Table 5-2.2-4 Supporting Requirements for HLR-SFR-C

The basis and methodologies used to establish the fragility threshold for SSCs shall be defined (HLR-SFR-C).

Index No. SFR-C	Capability Category I	Capability Category II
SFR-C1	SPECIFY the basis for defining inherently rugged components.	
SFR-C2	SPECIFY the basis and methodologies established for achieving the fragility threshold defined in SR SPR-B5.	

Table 5-2.2-5 Supporting Requirements for HLR-SFR-D

The Seismic Fragility Analysis shall incorporate the data and findings of walkdown(s) of the plant to establish or confirm as-built, as-operated conditions (HLR-SFR-D).

Index No. SFR-D	Capability Category I	Capability Category II
SFR-D1	CONFIRM that SSCs and associated anchorage that are assigned fragility threshold values satisfy the bases defined in HLR-SFR-C.	
SFR-D2	EVALUATE the seismic capacity of the as-designed, as-built, and as-operated plant conditions via a walkdown.	
SFR-D3	IDENTIFY seismic vulnerabilities in a manner that ensures the seismic-fragility estimations in SR SFR-E2 are conservative.	IDENTIFY seismic vulnerabilities in a manner that ensures the seismic-fragility calculations in SR SFR-E2 are realistic and plant specific.
SFR-D4	EVALUATE potential functional and structural failure mechanisms, equipment anchorage, and support load path.	
SFR-D5	IDENTIFY credible seismic-induced failures (including spray) for the flood sources provided in SR SPR-C3.	
SFR-D6	IDENTIFY credible seismic-induced failures for the fire ignition sources provided in SR SPR-C4.	
SFR-D7	IDENTIFY potential damaging seismic interactions that are credible and may compromise the SSCs' intended functions (see SR SPR-C6) or human actions (see SR SPR-D5).	

Table 5-2.2-6 Supporting Requirements for HLR-SFR-E

The Seismic Fragility Analysis shall be performed for relevant failure mechanisms affecting the failure modes modeled in the plant-response analysis (HLR-SFR-E).

Index No. SFR-E	Capability Category I	Capability Category II
SFR-E1	For those failure modes identified in SR SPR-C6, IDENTIFY conservative bounding failure mechanisms of structures (e.g., sliding, overturning, yielding, and excessive drift), equipment (e.g., anchorage failure, functional failure, impact with adjacent equipment or structures, and bracing failure), and soil (e.g., liquefaction, slope instability, and excessive differential settlement) (see SR SFR-D2, SR SFR-D3, and SR SFR-D4).	For those failure modes identified in SR SPR-C6 that are risk significant, IDENTIFY relevant and realistic failure mechanisms of structures (e.g., sliding, overturning, yielding, and excessive drift), equipment (e.g., anchorage failure, functional failure, impact with adjacent equipment or structures, and bracing failure), and soil (e.g., liquefaction, slope instability, and excessive differential settlement). For non-risk-significant failure modes, use the requirements of Capability Category I (CC-I) (see SR SFR-D2, SR SFR-D3, and SR SFR-D4).
SFR-E2	ESTIMATE conservative seismic fragilities for the failure mechanisms of interest identified in SR SFR-E1 using plant-specific data or JUSTIFY the use of generic fragility data (e.g., fragility test data, generic seismic qualification test data, and earthquake experience data) or conservative assumptions for the SSCs as being appropriate for the plant.	CALCULATE realistic seismic fragilities for the failure mechanisms of interest identified in SR SFR-E1 using plant-specific data or JUSTIFY (e.g., through the calculation of SCDF and SLERF per HLR-SPR-E) the use of generic fragility data (e.g., fragility test data, generic seismic qualification test data, and earthquake experience data) or conservative assumptions for any SSCs as being appropriate for the plant or by showing no masking or differences in insights.

Table 5-2.2-6 Supporting Requirements for HLR-SFR-E (Cont'd)

The Seismic Fragility Analysis shall be performed for relevant failure mechanisms affecting the failure modes modeled in the plant-response analysis (HLR-SFR-E).

Index No. SFR-E	Capability Category I	Capability Category II
SFR-E3	ESTIMATE contact-chatter seismic fragilities for relays and other similar devices that affect SSCs identified in the systems analysis (see SR SPR-B6).	CALCULATE contact-chatter seismic fragilities using plant-specific data or JUSTIFY the use of generic fragility data for relays and other similar devices that affect risk-significant SSCs and that are identified in the systems analysis (see SR SPR-B6).
SFR-E4	ESTIMATE seismic fragilities for credible seismic-induced flood sources (see SR SFR-D5) and seismic-induced fire ignition sources (see SR SFR-D6).	CALCULATE seismic fragilities using plant-specific data or JUSTIFY the use of generic fragility data for credible seismic-induced flood sources (see SR SFR-D5) and seismic-induced fire ignition sources (see SR SFR-D6) that are risk-significant contributors.
SFR-E5	IDENTIFY the sources of uncertainty, the related assumptions, and reasonable alternatives of the Seismic Fragility Analysis in a manner that supports the applicable requirements of SR SPR-E8.	

Table 5-2.2-7 Supporting Requirements for HLR-SFR-F

The documentation of the Seismic Fragility Analysis shall provide traceability of the work (HLR-SFR-F).

Index No. SFR-F	Capability Category I	Capability Category II
SFR-F1	DOCUMENT the process used in the Seismic Fragility Analysis specifying what is used as input, the applied methods, and the results. Address the following and other details needed to fully document how the set of SRs are satisfied: *(a)* seismic response analysis *(b)* inherently rugged and fragility threshold methodology *(c)* walkdown procedures *(d)* walkdown team composition and member qualification *(e)* walkdown observations and conclusions *(f)* review of design documents *(g)* identification of relevant failure mechanisms for each SSC *(h)* method of capacity evaluation *(i)* estimation or calculation of fragility parameter values for each SSC modeled (median capacity, logarithmic standard deviation representing the randomness in median capacity, and logarithmic standard deviation representing the uncertainty in median capacity), and sources of information *(j)* fragility correlation	
SFR-F2	DOCUMENT the sources of model uncertainty, related assumptions, and reasonable alternatives associated with the Seismic Fragility Analysis that are identified in SR SFR-E5.	

5-2.3 SEISMIC PLANT RESPONSE ANALYSIS (SPR)

5-2.3.1 Objectives

The primary objectives of the Seismic Plant Response Analysis are to

(a) develop a plant-response model that includes seismically induced initiating events and other failures and the plant's response to them

(b) develop accident sequences based on the plant configuration and the initiating events and failures

(c) integrate the Seismic Hazard Analysis and the Seismic Fragility Analysis with the Seismic Plant Response Analysis to quantify the seismic plant-response model, that is, to estimate the frequency of reaching the undesired end states of core damage or a large early release

(d) identify risk-significant contributors to SCDF and SLERF

(e) assess the impact of analysis limitations and uncertainties on the results

(f) document the Seismic Plant Response Analysis to provide traceability of the work

The following items are assumed:

(a) Relative to the systems-analysis requirements contained herein, the SPRA analysis team possesses a full-scope, internal-events at-power, Level 1 and LERF PRA, developed either before or concurrently with the SPRA.

(b) The internal-events PRA is then used as the basis for the SPRA systems analysis.

(c) It is recognized that the capability and completeness of the SPRA is a function of the capability and completeness of the internal-events at-power PRA.

If these assumptions are not valid, then such an internal-events PRA generally would be needed before the SPRA systems-analysis work could proceed.

The aforementioned objectives form the basis for the six HLRs for Seismic Plant Response Analysis stated in Table 5-2.3-1.

Table 5-2.3-1 High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Seismic Plant Response Analysis (SPR)

Designator	Requirement
HLR-SPR-A	The seismic plant-response model shall include seismically induced initiating events that cause risk-significant accident sequences and/or risk-significant accident-progression sequences.
HLR-SPR-B	The seismic plant-response model shall include seismic-induced SSC failures, non-seismic-induced SSC failures, unavailabilities, human errors, and multi-unit effects that can lead to core damage or large early release.
HLR-SPR-C	The list of SSCs selected for Seismic Fragility Analysis shall include the SSCs that contribute to accident sequences included in the seismic plant-response model.
HLR-SPR-D	Human actions credited in the Seismic Plant Response Analysis shall consider seismic-specific challenges to human performance.
HLR-SPR-E	The analysis to quantify CDF and LERF shall integrate the Seismic Hazard Analysis, the Seismic Fragility Analysis, and the Seismic Plant Response Analysis, including uncertainties.
HLR-SPR-F	The documentation of the Seismic Plant Response Analysis shall provide traceability of the work and interpretation of the risk profile for the plant.

Table 5-2.3-2 Supporting Requirements for HLR-SPR-A

The seismic plant-response model shall include seismically induced initiating events that cause risk-significant accident sequences and/or risk-significant accident-progression sequences (HLR-SPR-A).

Index No. SPR-A	Capability Category I	Capability Category II
SPR-A1	By using a systematic process and a review of relevant industry experience, IDENTIFY seismically induced initiating events caused directly by the seismic event [e.g., loss of off-site power (LOOP), loss of coolant accident (LOCA), LOOP-LOCA, LOCA followed by an anticipated transient without scram (ATWS)].	
SPR-A2	By using a systematic process and a review of relevant industry experience, IDENTIFY seismically induced hazard events resulting from secondary hazards (e.g., seismically induced internal flooding, external flooding, and fire ignition sources) including those identified in HLR-SHA-H that can themselves induce initiating events or fail SSCs modeled in the SPRA.	
SPR-A3	ENSURE that the initiating events included in the Seismic Plant Response Analysis represent industry experience (e.g., through review of plant-specific response to past seismic events, as well as other available seismic risk evaluations for nuclear plants).	
SPR-A4	INCLUDE in the seismic plant-response model the initiating events identified in SR SPR-A1, SR SPR-A2, and SR SPR-A3 that cause risk-significant accident-sequences and/or risk-significant accident progression sequences.	

Table 5-2.3-3 Supporting Requirements for HLR-SPR-B

The seismic plant-response model shall include seismic-induced SSC failures, non-seismic-induced SSC failures, unavailabilities, human errors, and multi-unit effects that can lead to core damage or large early release (HLR-SPR-B).

Index No. SPR-B	Capability Category I	Capability Category II
SPR-B1	USE the accident sequences and the systems logic model from the internal-event at-power PRA model as the basis for the SPRA plant-response model.	
SPR-B2	ENSURE that significant deficiencies identified during peer review for the internal events and other hazard PRAs that are relevant to the results of the SPRA are resolved and incorporated into the development of the SPRA plant-response model.	
SPR-B3	INCLUDE seismically induced failures corresponding to the failure modes of interest in the SPRA plant-response model (e.g., tank rupture, pump failure to start/run) (see SR SPR-C6).	
SPR-B4	MODEL the fragility correlation of seismically induced SSC failures consistently with information provided in SR SFR-A2. JUSTIFY the correlation approach used (e.g., by performing sensitivity studies to assess the contribution to the risk results).	
SPR-B5	DEFINE a fragility threshold that, when integrated with the hazard, satisfies SCR-2 in Table 1-1.8-1.	
SPR-B6	Using a systematic process, INCLUDE in the system analysis the effects of those relays or similar devices whose contact chatter results in the unavailability or spurious actuation of SSCs that are risk-significant contributors.	
SPR-B7	ASSESS the safe and stable end state of the seismic-induced accident sequences. SATISFY SR SC-A5 in Part 2 at CC-I for Success Criteria, except where the requirements are not applicable, to confirm that sustained impacts on plant accessibility and emergency response capability do not invalidate the assumed mission time.	ASSESS the safe and stable end state of the seismic-induced accident sequences. SATISFY SR SC-A5 in Part 2 at Capability Category II (CC-II) for Success Criteria, except where the requirements are not applicable, to confirm that sustained impacts on plant accessibility and emergency response capability do not invalidate the assumed mission time.
SPR-B8	If new logic is added to the SPRA (e.g., new system modeling, new or modified accident sequences), SATISFY HLR-AS-A and HLR-AS-B for accident-sequence analysis; HLR-SC-A and HLR-SC-B for Success Criteria analysis; HLR-SY-A and HLR-SY-B for Systems Analysis; HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D for Data Analysis; and HLR-HR-D for Human Reliability Analysis (specifically for pre-initiators) in Part 2 at CC-I except where the requirements are not applicable.	If new logic is added to the SPRA (e.g., new system modeling, new or modified accident sequences), SATISFY HLR-AS-A and HLR-AS-B for accident-sequence analysis; HLR-SC-A and HLR-SC-B for Success Criteria analysis; HLR-SY-A and HLR-SY-B for Systems Analysis; HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D for Data Analysis; and HLR-HR-D for Human Reliability Analysis (specifically for pre-initiators) in Part 2 at CC-II except where the requirements are not applicable.
SPR-B9	For any seismic-induced internal flood retained in the SPRA, SATISFY HLR-IFSN-A and SR IFQU-A1, SR IFQU-A2, SR IFQU-A3, and SR IFQU-A4 for Internal Flood Scenario Development in Part 3 at CC-I except where the requirements are not applicable.	For any seismic-induced internal flood retained in the SPRA, SATISFY HLR-IFSN-A and SR IFQU-A1, SR IFQU-A2, SR IFQU-A3, and SR IFQU-A4 for Internal Flood Scenario Development in Part 3 at CC-II except where the requirements are not applicable.
SPR-B10	For any seismic-induced fire ignition source retained in the SPRA, SATISFY HLR-PRM-A and HLR-PRM-B for the Internal Fire Plant Response Model in Part 4 at CC-I except where the requirements are not applicable.	For any seismic-induced fire ignition source retained in the SPRA, SATISFY HLR-PRM-A and HLR-PRM-B for the Internal Fire Plant Response Model in Part 4 at CC-II except where the requirements are not applicable

Table 5-2.3-3 Supporting Requirements for HLR-SPR-B (Cont'd)

The seismic plant-response model shall include seismic-induced SSC failures, non-seismic-induced SSC failures, unavailabilities, human errors, and multi-unit effects that can lead to core damage or large early release (HLR-SPR-B).

Index No. SPR-B	Capability Category I	Capability Category II
SPR-B11	For any seismic-induced external flooding hazards explicitly retained in the SPRA, SATISFY HLR-XFHA-B; HLR-XFFR-A, HLR-XFFR-B, HLR-XFFR-C, and HLR-XFFR-D; and HLR-XFPR-A, HLR-XFPR-B, HLR-XFPR-C, HLR-XFPR-D, and HLR-XFPR-E for external flood scenario development in Part 8 at CC-I except where the requirements are not applicable.	For any seismic-induced external flooding hazards explicitly retained in the SPRA, SATISFY HLR-XFHA-A and HLR-XFHA-B; HLR-XFFR-A, HLR-XFFR-B, HLR-XFFR-C, and HLR-XFFR-D; and HLR-XFPR-A, HLR-XFPR-B, HLR-XFPR-C, HLR-XFPR-D, and HLR-XFPR-E for external flood scenario development in Part 8 at CC-II except where the requirements are not applicable.
SPR-B12	For all other secondary hazards explicitly retained in the SPRA, SATISFY SR XFR-A4, SR XFR-A5, and HLR-XPR-B for scenario development in Part 9 at CC-I except where the requirements are not applicable.	For all other secondary hazards explicitly retained in the SPRA, SATISFY SR XFR-A4, SR XFR-A5, and HLR-XPR-B for scenario development in Part 9 at CC-II except where the requirements are not applicable.
SPR-B13	For multi-unit sites, ENSURE that the multi-unit impacts of a seismic event are captured in the seismic plant-response model as appropriate.	

Table 5-2.3-4 Supporting Requirements for HLR-SPR-C

The list of SSCs selected for Seismic Fragility Analysis shall include the SSCs that contribute to accident sequences included in the seismic plant-response model (HLR-SPR-C).

Index No. SPR-C	Capability Category I	Capability Category II
SPR-C1	USE the internal-events systems model as the basis for developing a SEL to support the Seismic Fragility Analysis.	
SPR-C2	INCLUDE in the SEL additional SSCs (e.g., structures, passive components, relays, panels, and cabinets that house PRA components) that may not be present in the internal-events model and in other hazard PRAs but that require evaluation in the SPRA.	
SPR-C3	INCLUDE in the SEL internal flood sources (as defined in SR IFQU-G2 in Part 3) that have been identified in SR SPR-A2.	
SPR-C4	INCLUDE in the SEL fire ignition sources (as defined in SR FQ-G1 in Part 4) that have been identified in SR SPR-A2.	
SPR-C5	INCLUDE in the SEL SSCs that are inducing or are affected by the initiators resulting from the secondary hazards identified in SR SPR-A2.	
SPR-C6	For the SSCs identified in SR SPR-C1, SR SPR-C2, SR SPR-C3, SR SPR-C4, and SR SPR-C5, IDENTIFY the failure mode(s) of interest for the Seismic Fragility Analysis to be performed.	

Table 5-2.3-5 Supporting Requirements for HLR-SPR-D

Human actions credited in the Seismic Plant Response Analysis shall consider seismic-specific challenges to human performance (HLR-SPR-D).

Index No. SPR-D	Capability Category I	Capability Category II
SPR-D1	IDENTIFY the human failure events (HFEs; including recovery actions) from the selected baseline PRA that are relevant in the context of the SPRA.	
SPR-D2	For human response actions relevant to the Seismic Plant Response Analysis, SATISFY HLR-HR-E in Part 2 at CC-I except where the requirements are not applicable.	For human response actions relevant to Seismic Plant Response Analysis, SATISFY HLR-HR-E in Part 2 at CC-II except where the requirements are not applicable.
SPR-D3	For definition and specification of HFEs for human response actions identified in SR SPR-D2, SATISFY HLR-HR-F in Part 2 at CC-I except where the requirements are not applicable.	For definition and specification of HFEs for human response actions identified in SR SPR-D2, SATISFY HLR-HR-F in Part 2 at CC-II except where the requirements are not applicable.
SPR-D4	For treatment of recovery actions identified in SR SPR-D2, SATISFY HLR-HR-H in Part 2 except where the requirements are not applicable.	
SPR-D5	SATISFY HLR-HR-G in Part 2 at CC-I except where the requirements are not applicable, considering relevant seismic-related effects on control room and ex-control room post-initiator actions. When addressing influencing factors and the timing considerations covered in SR HR-G3, SR HR-G4, and SR HR-G5 in Part 2, INCLUDE the effect of the seismic hazard on the control room and ex-control room human actions, for example, *(a)* training and procedures *(b)* additional workload and stress *(c)* effects of the seismic event on mitigation *(d)* required response, timing, and accessibility *(e)* potential for physical harm *(f)* seismic-specific job aids and training	SATISFY HLR-HR-G in Part 2 at CC-II except where the requirements are not applicable, considering relevant seismic-related effects on control room and ex-control room post-initiator actions. When addressing influencing factors and the timing considerations covered in SR HR-G3, SR HR-G4, and SR HR-G5 in Part 2, INCLUDE the effect of the seismic hazard on the control room and ex-control room human actions, for example, *(a)* training and procedures *(b)* additional workload and stress *(c)* effects of the seismic event on mitigation *(d)* required response, timing, and accessibility *(e)* potential for physical harm *(f)* seismic-specific job aids and training

Table 5-2.3-6 Supporting Requirements for HLR-SPR-E

The analysis to quantify CDF and LERF shall integrate the Seismic Hazard Analysis, the Seismic Fragility Analysis, and the Seismic Plant Response Analysis, including uncertainties (HLR-SPR-E).

Index No. SPR-E	Capability Category I	Capability Category II
SPR-E1	In the quantification of SCDF and SLERF on a reactor-year basis, INTEGRATE the Seismic Hazard Analysis, the Seismic Fragility Analysis, and the Seismic Plant Response Analysis in the seismic plant-response model.	
SPR-E2	ADDRESS the overestimation of risk due to rare-event approximations (e.g., where fragilities approach 1.0).	
SPR-E3	ENSURE that the discretization of the hazard curves (e.g., the size and number of bins used to discretize the hazard curve or other numerical methods used to incorporate the hazard curve in the integration) is appropriate to demonstrate convergence of SCDF and SLERF.	
SPR-E4	When quantifying SCDF, SATISFY SR QU-A2, SR QU-A4, and SR QU-A5; SR QU-B1, SR QU-B2, and SR QU-B3; SR QU-B5, SR QU-B6, SR QU-B7, SR QU-B8, SR QU-B9, and SR QU-B10; SR QU-C1, SR QU-C2, and SR QU-C3; SR QU-D1, SR QU-D2, and SR QU-D3; and SR QU-D5, SR QU-D6, and SR QU-D7, in Part 2 except where the requirements are not applicable	
SPR-E5	USE the mean hazard, mean fragilities, and the seismic plant-response model to generate point estimates for SCDF and SLERF through the quantification process.	QUANTIFY the mean SCDF and SLERF and propagate the parameter uncertainty that results from each input (i.e., the seismic hazard, the seismic fragilities, and the systems analysis) through the quantification process.
SPR-E6	In the analysis of SLERF, SATISFY SR LE-A2; SR LE-C2, SR LE-C3, SR LE-C4, and SR LE-C12; SR LE-D3; SSR LE-E3; and SR LE-F1 and SR LE-F2 in Part 2 at CC-I for LERF Analysis except where the requirements are not applicable.	In the analysis of SLERF, SATISFY SR LE-A2; SR LE-C2, SR LE-C3, SR LE-C4, and SR LE-C12; SR LE-D3; SSR LE-E3; and SR LE-F1 and SR LE-F2 in Part 2 at CC-II for LERF Analysis except where the requirements are not applicable.
SPR-E7	IDENTIFY, in the Seismic Plant Response Analysis, sources of model uncertainty, the related assumptions, and reasonable alternatives in a manner that supports the applicable requirements of SR SPR-E8.	
SPR-E8	SATISFY SR QU-E1 in Part 2 with the additional assumptions in SR SHA-I2, SR SFR-F2, and SR SPR-F3.	

Table 5-2.3-7 Supporting Requirements for HLR-SPR-F

The documentation of the Seismic Plant Response Analysis shall provide traceability of the work and interpretation of the risk profile for the plant (HLR-SPR-F).

Index No. SPR-F	Capability Category I	Capability Category II
SPR-F1	DOCUMENT the process used in the Seismic Plant Response Analysis specifying what is used as input, the applied methods, and the results. Address the following and other details needed to fully document how the set of SRs are satisfied: *(a)* SEL development and disposition of SSCs *(b)* the specific modifications made in the internal-events PRA model to produce the SPRA model and their basis *(c)* those seismic-related influences that affect methods, processes, or assumptions used, as well as the identification and quantification of the HFEs and the human error probabilities *(d)* the major outputs of an SPRA, such as mean SCDF, mean SLERF, uncertainty distributions on SCDF and SLERF, results of sensitivity studies, and risk-significant contributors	
SPR-F2	DOCUMENT the risk-significant contributors (e.g., initiating events, accident sequences, basic events) to SCDF and SLERF in the PRA results summary, and DESCRIBE risk-significant accident sequences or risk contributors in accordance with the definitions provided in Section 1-2.2.	
SPR-F3	DOCUMENT the sources of model uncertainty, related assumptions, and reasonable alternatives associated with the Seismic Plant Response Analysis identified in SR SPR-E7.	
SPR-F4	DOCUMENT limitations in the quantification process that would impact applications.	

NONMANDATORY APPENDIX 5-A
SEISMIC PROBABILISTIC RISK ASSESSMENT COMMENTARY

5-A.1 BACKGROUND AND OVERVIEW

This Nonmandatory Appendix provides notes and general explanatory material tied to specific SRs as stated in Part 5 of this Standard. The material contained in this Appendix is nonmandatory and, as such, does not establish new requirements: rather, the material is intended to clarify the intent of an SR, explain jargon that might be used in an SR, and/or provide examples of analysis approaches that would meet the intent of the SR.

In recent years, advances in seismic ground motion models coupled with unprecedented seismic events have sparked the advancement of SPRAs in the nuclear industry worldwide. For example, Generic Issue 199 in 2010 [5-A-1] pointed out that some existing nuclear power plants in the central eastern United States may be at higher seismic risk as a result of increased seismic hazard estimates. Furthermore, the 2011 Fukushima Daiichi nuclear accident triggered a wave of risk and safety evaluations for nuclear plants across the world, for example, stress tests in Europe and the Near-Term Task Force Recommendation 2.1 [5-A-2] for the United States. In most instances, licensees used these evaluations to reevaluate the seismic hazard at the site and develop SPRAs to address beyond-design seismic events, thus setting the stage for future risk-informed programs.

Recent SPRAs have advanced the state of practice for modeling and seismic risk quantification of plant-systems response. For instance, the assessments of seismically induced fires have triggered an industry-wide effort to improve understanding of the correlation among mechanical failure modes, location of fuel sources, and probabilities of ignition that is still in process. This effort promises a more accurate estimate of fire scenarios given a range of ground-shaking intensity levels. Considerable advances have also been made in the field of seismic hazard. New and improved GMPEs and seismic source characterization models have been developed [5-A-3] to improve the estimates of uncertainty in PSHA and site response analyses. Continued advances in computational tools have facilitated the use of nonlinear structural analysis to estimate seismic response of structures against high levels of input ground motion.

These and other advances justify revision of the requirements in Part 5 of this Standard. This revision incorporates essential lessons learned from recent SPRAs, incorporates advances in technology, and fosters the integration and collaboration among all technical elements.

The new commentary presented herein has been developed as a companion document to the requirements in Part 5. This new commentary replaces the Notes in Addendum B [5-A-4] and the Part 5 Case [5-A-5]. In essence, the commentary aims to facilitate consistent and clear interpretation of the requirements across the multiple disciplines typically involved in an SPRA. The commentary provides discussion on technical bases, practical examples from recent SPRAs, and notes cross-referencing technical elements. The commentary is organized following the same structure and sequence of the SRs in Part 5. In other words, commentary and discussions are provided for HLRs and SRs for each technical element, starting with Seismic Hazard Analysis and followed by Seismic Fragility Analysis and Seismic Plant Response Analysis.

5-A.2 COMMENTARY TO SEISMIC AT-POWER TECHNICAL ELEMENTS AND REQUIREMENTS

A Seismic Hazard Analysis provides both an assessment of vibratory motion by performing a PSHA and assessing associated (e.g., fault rupture) and secondary nonvibratory hazards (e.g., landslides, soil liquefaction, soil settlement, and earthquake-induced external flooding). As defined in Section 1-2.2, secondary hazards are those that are induced by the primary hazard, which in this case is vibratory ground motion.

The PSHA is a component of the broader Seismic Hazard Analysis. The results of the PSHA are usually expressed in terms of the frequency distribution of the peak value of a series of horizontal ground motion parameters [e.g., peak ground acceleration (PGA)] over a range of specified time intervals. As described in NUREG-2213 [5-A-6], NUREG-2117 [5-A-7], and NUREG/CR-6372 [5-A-8], steps of this analysis are typically broken into three areas: *(a)* seismic source characterization, *(b)* GMC, and *(c)* site response. The results of a PSHA can also be used to develop uniform hazard spectra (also known as response spectra). Seismic Hazard Analyses also include assessment of vertical ground motion, which is typically calculated using the horizontal ground motion coupled with a vertical-to-horizontal (V/H) ratio.

Seismic Hazard Analysis and its requirements are organized in the following way in this Standard:

HLR-SHA-A	PSHA methodology
HLR-SHA-B	Data collection
HLR-SHA-C	Seismic source characterization
HLR-SHA-D	Ground motion characterization
HLR-SHA-E	Site response
HLR-SHA-F	Uncertainty
HLR-SHA-G	Spectral shape for fragility analysis
HLR-SHA-H	Nonvibratory hazards
HLR-SHA-I	Documentation

Currently, the state of practice for PSHA model development follows guidelines originally developed by the Senior Seismic Hazard Analysis Committee (SSHAC) [5-A-8], as further substantially developed in NUREG-2213 [5-A-6] and NUREG-2117 [5-A-7] (hereafter this body of work is noted as the "SSHAC guidelines"). The SSHAC guidelines describe a structured approach of PSHA model development that addresses most of the requirements related to HLR-SHA-A, HLR-SHA-B, HLR-SHA-C, HLR-SHA-D, and HLR-SHA-F. The SSHAC guidelines have significant documentation requirements consistent with HLR-SHA-I. The SSHAC guidelines define four levels of study, with each study level increasing in complexity. Levels 3 and 4, which are equally acceptable for developing PSHAs appropriate for nuclear applications, provide the highest level of assurance that the objectives of the SSHAC process are met. Level 2 studies can be used to update or refine regional studies for site-specific use, as described in NUREG-2213 [5-A-6] and NUREG-2117 [5-A-7]. Level 1 and 2 studies also provide the basis for an assessment of existing studies in some cases (see, e.g., the process described by Kammerer et al. [5-A-9]). Regardless of the SSHAC study level, the objective of the SSHAC process is the same: to develop a model that represents the center, body, and range of the technically defensible interpretations of the available earth science information. For further details on PSHA model development and analysis methods, the reader is referred to NUREG-2213 [5-A-6] and NUREG-2117 [5-A-7]. An example case study of a PSHA that uses this guidance is found in NUREG 2115 [5-A-10]. Typical results of a PSHA include families of seismic-hazard curves in terms of PGA or Sa values at different frequencies and site-specific ground motion response spectra.

PSHA is a site-specific analysis that may or may not build on available regional studies. If a regional seismic source characterization or GMC study is used as a starting point, the requirements related to use of an existing study apply. An important change in the current revision of this Standard is the removal of the previous HLR-SHA-H, which was focused on cases where a previously existing PSHA study was used. This change was made to avoid redundancy with other high-level requirements that specify technical requirements that stand regardless of whether a PSHA study is new or existing. Instead, new SRs (i.e., SR SHA-B4, SR SHA-C4, and SR SHA-D4) were added to ensure that new information (e.g., data, models, and methods) is appropriately considered. In the context of an SPRA study, information is considered new if it was unknown when the previous model was developed or was known but not previously used either due to postdating the study "cutoff" date or due to its state as not fully mature or publicly available at that time.

The identification and quantification of uncertainty is an important part of all aspects of Seismic Hazard Analysis, and a significant level of effort and attention is applied throughout the Seismic Hazard Analysis model-building process. Seismic Hazard Analysis differs from other aspects of SPRA (and indeed other aspects of PRA) in this regard. In PSHA, two different classes of uncertainties (as defined in Section 1-2.2) are identified and addressed throughout the process. Lack-of-knowledge uncertainties (epistemic uncertainties) arise from imperfect scientific understanding that can, in principle, be reduced through additional research and acquisition of data. Epistemic uncertainties are often addressed in the modeling process through use of logic trees or sensitivity studies, which provide a quantifiable and transparent approach and lead to a family of hazard curves. The aleatory or random uncertainties (often called "aleatory variability" within the technical community) are those uncertainties that, for all practical purposes, cannot be known in detail or cannot be reduced. Aleatory variability is typically addressed by using parameter distributions.

These two classes of uncertainties should be identified, quantified, and tracked separately throughout the PSHA process to the extent possible. Although some applications may use the mean hazard curve that includes combined uncertainties instead of the complete family of hazard curves (see NUREG-1407 [5-A-11] for examples), maintaining the distinction in the nature of uncertainties is crucial for development of the PSHA to be used in SPRA. Understanding the uncertainty bands is also useful for identification of vulnerabilities and ranking dominant sequences and contributors. In PSHA, this distinction is maintained to understand and communicate the sources of uncertainties throughout the process. This need to maintain separation between epistemic and aleatory uncertainties for SPRA differs from cases where PSHA is to be used only for its more traditional purpose of development of seismic design parameters.

The hazard estimates depend on uncertain estimates of ground motion propagation, upper-bound magnitudes, and the geometry of the postulated seismic sources, as well as on numerical treatment of source boundaries. Such uncertainties are included in the hazard analysis by using parameter distributions and logic trees. Parameter distributions are used to quantify aleatory uncertainties. Epistemic uncertainties are documented and quantified by using logic trees with probabilities assigned to alternative data, models, and methods. The annual frequencies of exceeding specified values of the ground motion parameter are displayed as a family of curves with different confidence levels.

Site response analyses are performed to quantify how near-surface geologic materials and their dynamic properties modify seismic vibratory motions entering the site from the underlying rock. In the past, site response analysis was performed as a separate calculation by using as input the results from a rock-based PSHA. However, recently it has been more common for site response to be directly incorporated into the PSHA integral by using Method 3 of NUREG/CR-6728 [5-A-12]. If it is not directly incorporated into the PSHA, the soil amplification functions from the site response are applied to the uniform hazard spectra. In current practice, the site response aspects of Seismic Hazard Analysis are not subject to all the requirements of the SSHAC process, although the most important aspects of the SSHAC process are increasingly applied. As with other elements of Seismic Hazard Analysis, the identification, quantification, and tracking of uncertainties are key components of site response evaluation activities.

Over the course of the current revision of this Standard, methods for addressing human-induced seismicity (e.g., seismicity caused by hydraulic fracturing and wastewater injection) have been undergoing significant development. However, in the past decade, a number of SPRA studies and peer reviews were conducted as part of the post-Fukushima efforts in the United States and, as a result, some approaches were developed out of necessity. The approaches differed somewhat depending on whether the seismicity is related to the construction of dams and reservoirs that are likely to remain in place permanently or to hydraulic fracturing and wastewater injection, which may come and go over time. The practices and concepts applied to address the issue of human-induced seismicity are discussed in the SRs related to HLR-SHA-H, for the user's consideration. In any case, it is important to ensure that the approach to evaluation of hazards resulting from human-induced events is consistent with the objectives of the SPRA being conducted.

5-A.2.1 Commentary to Seismic Hazard Analysis (SHA)

Table 5-A.2.1-1 Commentary to High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Seismic Hazard Analysis (SHA)

Designator	Commentary
HLR-SHA-A	HLR-SHA-A requires that the basis for the calculation of the frequencies of exceeding different levels of seismic horizontal vibratory ground motion at the site shall be a site-specific PSHA that represents the center, body, and range of the technically defensible interpretations. The SSHAC guidelines describe the concept of center, body, and range and a structured process achieving these goals in a transparent way. The SSHAC process can be applied for assessing seismic vibratory ground motion on both a site and a regional level. Site-specific PSHA that includes site-specific site response analysis, if appropriate, should be performed consistently with the SSHAC guidelines.
HLR-SHA-B	The SSHAC process begins with a comprehensive effort to identify, collect, and evaluate all available data, models, and methods for PSHA model development, consistent with the requirements of HLR-SHA-B. The effort should follow guidance in NUREG-2213 [5-A-6] and NUREG-2117 [5-A-7]. Data and information relevant to the other elements of the site-specific Seismic Hazard Analysis, including site response and other nonvibratory and secondary hazards, must also be collected. NRC has provided guidance for data collection expected for licensing of new reactors ([5-A-13], [5-A-14]). Efforts to identify and collect information related to human-induced seismicity are also generally included in HLR-SHA-B.
HLR-SHA-C	The SSHAC guidelines ([5-A-6], [5-A-7]) provide guidance on seismic source characterization modeling for input to PSHA evaluations. An example of a regional study conducted using the SSHAC Level 3 approach is documented in NUREG 2115 [5-A-10].
HLR-SHA-D	The SSHAC guidelines ([5-A-6], [5-A-7]) provide guidance on GMC modeling for input to PSHA evaluations.

Table 5-A.2.1-1 Commentary to High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Seismic Hazard Analysis (SHA) (Cont'd)

Designator	Commentary
HLR-SHA-E	Approaches for incorporating site response in the PSHA are provided in NUREG/CR-6728 [5-A-12], with Method 3 being preferred, particularly for new plants.
HLR-SHA-F	The SSHAC process requires the identification, analysis, and documentation of uncertainties throughout the PSHA model-development process. HLR-SHA-F also addresses uncertainties associated with other aspects of the broader Seismic Hazard Analysis. A mean estimate of the frequency of exceedance at any PGA and other spectral frequencies is calculated based on the weighted sum of the frequencies of exceedance at this acceleration given by the different hazard curves; the weighting factor is the probability assigned to branch of the logic tree. Thus, the PSHA embeds uncertainties in the core of the methodology, and results are expressed in terms of likelihood (i.e., estimated probabilities in a given time period or estimated frequencies) that ground motions of various amplitudes will occur at a given site. Uncertainties must be carried through the site response analysis.
HLR-SHA-G	The spectral shape should be determined using the most risk-significant annual probability of exceedance. In some instances, the spectral shape at the design level is used as a starting point. In these cases, the shape of the response spectra at the most risk-significant annual probability of exceedance should be determined and checked against the design spectral shape.
HLR-SHA-H	Nonvibratory seismic hazards are addressed through a multistep process that begins with development of a list of potential hazards followed by screening for the hazard based on the potential for the hazard to occur at the site (not the potential impact of the hazard). If the hazard cannot be screened out, an analysis is performed to determine the probability of hazard levels appropriate for input to the fragility and plant-response evaluations. At the end of the process, the potential impact of the nonvibratory hazard is determined. Seismic-hazard experts involved in the identification, assessment, and peer review of nonvibratory seismic hazards generally have appropriate expertise for identifying, assessing, and possibly screening out human-induced seismicity resulting from nonstationary human activities (e.g., hydraulic fracturing and wastewater injection). As a result, many recent SPRA studies have treated the topic of human-induced seismicity within the requirements for HLR-SHA-H because human-induced seismicity has the potential to be screened out similar to other seismic hazards.
HLR-SHA-I	The documentation of the Seismic Hazard Analysis must provide traceability of the work. The Seismic Hazard Analysis includes both the PSHA and other elements (e.g., screening of secondary hazards), which are often in a large array of documents. As a result, best practices that were recently developed in response to recent peer-review activities include a Seismic Hazard Analysis "roadmap" that documents the location and history of development of the various aspects of the broader Seismic Hazard Analysis efforts.

Table 5-A.2.1-2 Commentary to Supporting Requirements for HLR-SHA-A

Index No. SHA-A	Commentary
SHA-A1	The SSHAC report [5-A-8] and related updated and more detailed guidance ([5-A-6], [5-A-7]) provide the defined process for conducting a PSHA that produces a model that represents the center, body, and range of the technically defensible interpretations, as defined in those references. These references have identified and provided guidance for four levels of hazard analysis. The SSHAC study level should be chosen consistently with the intended application following the SSHAC guidelines ([5-A-6], [5-A-7], [5-A-8]). The site-specific PSHA may start with a regional study developed using the SSHAC guidelines.
SHA-A2	No commentary provided.
SHA-A3	No commentary provided.
SHA-A4	No commentary provided.
SHA-A5	The specified lower-bound magnitude should be consistent with current practice. Regulatory Guide 1.208 [5-A-15] provides one acceptable approach to establishing a lower-bound magnitude for use in the Seismic Hazard Analysis.
SHA-A6	Regulatory Guide 1.208 [5-A-15] provides an acceptable approach to establishing the number of standard deviations to be included in the analysis of GMPEs. It should be noted that PSHA quantification software often has an option to apply "no truncation." However, the software must always apply an epsilon, even if very large, for purposes of computation. This epsilon should be noted in associated documentation.

Table 5-A.2.1-3 Commentary to Supporting Requirements for HLR-SHA-B

Index No. SHA-B	Commentary
SHA-B1	Guidelines as to when an existing study should be refined or replaced are provided in NUREG-2213 [5-A-6] and NUREG-2117 [5-A-7].
SHA-B2	No commentary provided.
SHA-B3	The geographical region around the site that is addressed in the PSHA can extend up to a radius of 1000 km. The actual size depends, among other factors, on regional characteristics. See Section 1.1 of Regulatory Guide 1.208 [5-A-15] for further discussion on this subject.
SHA-B4	This SR applies both when an existing site-specific PSHA study is used or when regional seismic source characterization and GMC models are used as the basis for a PSHA. One important feature in conducting a PSHA is to ensure that the key inputs represent the currently available data, models, and methods and that the PSHA represents the center, body, and range of technically defensible interpretations. In the context of an SPRA, information is considered to be "new" if it was unknown when the previous model was developed or was known but not previously used either due to postdating the study "cutoff" date or due to its state as not fully mature or publicly available at that time. Key inputs to a regional Seismic Hazard Analysis and the analysis results are periodically revised. Guidelines regarding when an existing regional study should be refined or replaced are provided in NUREG-2213 [5-A-6] and NUREG-2117 [5-A-7]. Importantly, when a regional model is changed (as opposed to augmented, such as with additional local faults), it is no longer considered to be the original model and no longer carries the SSHAC pedigree.
SHA-B5	No commentary provided.

Table 5-A.2.1-4 Commentary to Supporting Requirements for HLR-SHA-C

Index No. SHA-C	Commentary
SHA-C1	No commentary provided.
SHA-C2	NUREG-2213 [5-A-6] and NUREG/CR-6372 [5-A-8] provide a structured approach for conducting a PSHA consistent with the level of analysis defined in HLR-SHA-A. These references also provide a process for producing a seismic sources model that represents the center, body, and range of the technically defensible interpretations.
SHA-C3	The identification and inclusion of uncertainty is required because seismic sources are numerically characterized based on alternative interpretations and conceptual models that can include alternative geometries, alternative estimates of maximum earthquake magnitude, alternative earthquake recurrence models and parameters, and alternative approaches to treatments of point source and finite fault modeling ([5-A-6], [5-A-7]).
SHA-C4	In the context of an SPRA, information is considered to be "new" if it was unknown when the previous model was developed or was known but not previously used either due to postdating the study "cutoff" date or due to its state as not fully mature or publicly available at that time. Key inputs to a regional Seismic Hazard Analysis and the analysis results are periodically revised. Guidelines regarding when an existing regional study should be refined or replaced are provided in NUREG-2213 [5-A-6] and NUREG-2117 [5-A-7].
SHA-C5	SR SHA-C5 requires consideration and justification of the choice of SSHAC level used in the study that updates an existing seismic source characterization model. It is important to note that when a regional model is changed (as opposed to augmented, such as with additional local faults), it is no longer considered to be the original model and no longer carries the SSHAC pedigree, although it provides an efficient starting point for development of the new model.

Table 5-A.2.1-5 Commentary to Supporting Requirements for HLR-SHA-D

Index No. SHA-D	Commentary
SHA-D1	No commentary provided.
SHA-D2	The SSHAC guidelines ([5-A-6], [5-A-7], [5-A-8]) provide a structured approach for conducting a PSHA consistent with the level of analysis defined in HLR-SHA-A. These references also provide a process for producing a GMC model that represents the center, body, and range of the technically defensible interpretations.
SHA-D3	In developing the GMC model, all possible sources of uncertainty should be identified, evaluated, and (where appropriate) included in it. Uncertainties (e.g., sigma, the uncertainty around the point value for a given magnitude/distance pair), which are critical for appropriate assessment of hazard, are included. More recently, issues such as addressing uncertainties related to alternative magnitude-distance relationships and the need to ensure that the treatment of finite fault sources within PSHA quantification processes is consistent with GMC assumptions have been identified.
SHA-D4	In the context of an SPRA, information is considered to be "new" if it was unknown when the previous model was developed or was known but not previously used either due to postdating the study "cutoff" date or due to its state as not fully mature or publicly available at that time. Key inputs to a regional Seismic Hazard Analysis and the analysis results are periodically revised. Guidelines regarding when an existing regional study should be refined or replaced are provided in NUREG-2213 [5-A-6] and NUREG-2117 [5-A-7]. It is important to note that when a regional model is changed (as opposed to augmented, such as with additional local faults), it is no longer considered to be the original model and no longer carries the SSHAC pedigree, although it provides an efficient starting point for development of the new model.

Table 5-A.2.1-6 Commentary to Supporting Requirements for HLR-SHA-E

Index No. SHA-E	Commentary
SHA-E1	No commentary provided.
SHA-E2	No commentary provided.
SHA-E3	No commentary provided.

Table 5-A.2.1-7 Commentary to Supporting Requirements for HLR-SHA-F

Index No. SHA-F	Commentary
SHA-F1	The SSHAC guidelines ([5-A-6], [5-A-7], [5-A-8]) provide a structured approach for conducting a PSHA consistent with the level of analysis defined in HLR-SHA-A.
SHA-F2	No commentary provided.
SHA-F3	For site-specific studies that do not use regional models, sensitivity studies and intermediate results provide important information to reviewers about how some of the modeling assumptions distort the final results of a complex seismic-hazard process. Examples of useful sensitivity studies include an evaluation of alternative schemes used to assign weights to the individual expert models and an evaluation of the way different experts make different assignments of the regional seismicity to different zonation maps. Where regional studies are used, it is important to document how the sensitivity and uncertainty information from the regional model's documentation provides insights for the site being analyzed. SR SHA-F3 is focused on evaluation of uncertainties to be treated and peer reviewed within the PSHA study and SSHAC methodology. The PSHA-focused evaluations are generally common practice within this methodology and are conducted to understand the key issues within the PSHA. The treatment of uncertainties within the model development and quantification process impacts the shape and distribution of the family of resulting hazard curves. It is unproductive and inappropriate for the uncertainties identified within a PSHA conducted using the SSHAC guidelines to be further evaluated by using the PRA quantification model. The SSHAC guidelines process, including its peer-review process, has already incorporated thorough treatment of uncertainties.
SHA-F4	In contrast to SR SHA-F3, which is focused on the PSHA, SR SHA-F4 is targeted on other aspects of the Seismic Hazard Analysis that are treated outside the SSHAC process. In these cases (e.g., in the development of V/H models), epistemic uncertainties associated with the judgment of individual experts should be identified and evaluated through PRA model quantification to understand whether judgments made in the course of the Seismic Hazard Analysis have a large enough effect on the ultimate risk insights to warrant the application of additional effort such as broader evaluations, and perhaps broader logic trees, or focused peer review.

Table 5-A.2.1-8 Commentary to Supporting Requirements for HLR-SHA-G

Index No. SHA-G	Commentary
SHA-G1	The spectral shape determined in the Seismic Hazard Analysis should be based on site-specific analysis.
SHA-G2	Regulatory Guide 1.208 [5-A-15] provides one approach to establishing V/H spectral ratios, which can be combined with the appropriate horizontal spectra to derive vertical spectra. EPRI [5-A-16] provides guidance for developing mean V/H ratios for a range of site conditions (rock and soil) and levels of ground motion.

Table 5-A.2.1-9 Commentary to Supporting Requirements for HLR-SHA-H

Index No. SHA-H	Commentary
SHA-H1	SR SHA-H1 addresses development of the list of other seismic and secondary hazards requiring further evaluation for the SPRA. The list is developed by starting with a very broad list of other possible seismic and secondary hazards. Secondary hazards (e.g., landslides, soil liquefaction, soil settlement, and earthquake induced flooding) are those that result from ground motions. Other seismic hazards include the possibility for direct fault rupture. Recent practice has included human-induced seismicity in the list of potential other hazards to be evaluated. SR SHA-H1 is the first step in a process illustrated in the Figure 5-A.2-9.
SHA-H2	The appropriate approach used to justify the basis and methodology used for screening out other direct seismic hazards (e.g., fault displacement) or secondary hazards caused by vibratory ground motions (e.g., soil liquefaction, soil settlement, and earthquake-induced external flooding) is hazard and site specific and may occur at various stages in the evaluation. The flowchart (Figure 5-A.2-9) shows how information flows from SR SHA-H1 and SR SHA-H2 to other SRs. Justification for screening may be based on publicly available literature and prior hazard studies. An initial qualitative screening process in SR SHA-H2 can be applied to remove hazards where the hazard is physically not possible (e.g., tsunami hazard at a site far from the ocean) or is exceedingly rare (e.g., triggering of secondary hazard <1.0E-7 per year) as assessed by a demonstrably conservative deterministic analysis/assessment. There are two additional points at which screening of the hazard from inclusion in the SPRA model can occur if the hazard is not screened out based on Table 1-1.8-1. A second screening approach starts with the SEL and screens the SSCs from further consideration on an SSC-by-SSC basis. Screening Step 2 removes SSCs that cannot be impacted due to their location away from the hazard under consideration (e.g., an SSC is in a location that is not susceptible to liquefaction because it is founded on rock). Screening Step 3 removes SSCs that can be demonstrated to have sufficient capacities within the context of the SPRA given the hazard levels (e.g., the convolution of the fragility and hazard curves demonstrates a sufficiently low probability of failure). Because Screening Step 3 occurs after the work of developing fragility and hazard curves has been performed, the principal benefit is the simplification of the quantification model. Screening Steps 2 and 3 require interactions between hazard, fragility, and plant-response analysts. These screening methods should be considered within the framework of Table 1-1.8-1 and must give due consideration of the contribution to the cumulative impact due to simplifications of the model.
SHA-H3	If site conditions make it necessary to include other seismic hazards, the objective of the subsequent analysis is to estimate the frequency of hazard occurrence as a function of amplitude or intensity of the parameter appropriate for the failure mechanism(s) of interest. Because understanding the risk implications of other seismic hazards requires additional analysis within a PRA framework, the approach used to analyze additional hazards, as well as the parameters assessed, should be integrated with the fragility and model analysis activities. Requirements for seismically induced internal fire and flooding are addressed in SR SFR-D3, SR SFR-D4, and SR SPR-B10.
SHA-H4	This SR is focused on earthquake-induced external flooding hazards (e.g., upstream dam failure) that are not screened out in SR SHA-H2 and refers the user to the applicable requirements in HLR-XFHA-A, HLR-XFHA-B, HLR-XFHA-C, HLR-XFHA-D, HLR-XFHA-E, HLR-XFHA-F, and HLR-XFHA-G in Part 8 for calculating the frequencies of hazard parameters necessary to define the fragility for failure mechanisms of SEL items that may be impacted. This SR is required because there is an interface between seismic hazard and flooding hazard inherent in the earthquake-induced external flooding hazards; therefore, there is a need for consistency between the Parts and clarity as to which are the governing SRs.

Fig. 5-A.2-9 Flowchart showing information flows among Supporting Requirements

SHA	SFR	SPR	Notes
SHA-H1			Identify fault displacement and secondary hazards that may impact the site
SHA-H2			Determine if any secondary hazard can be screened entirely from further evaluation based on the overall hazard and the site (e.g., liquefaction on a rock site, very low probabilities of liquefaction for very low annual probabilities of exceedance ground motions, or no potential fault displacement phenomena in the site vicinity area)
		SPR-A2	Identify seismically induced initiating events due to secondary hazards that do not screen out in SHA-H2
		SPR-C1 to SPR-C6	Define SEL including SSCs associated with hazard events identified in SPR-A2 and their failure modes
SHA-H2			SHA-H2 Screening Step 2 – Remove from consideration impact to SEL items by secondary hazards if they cannot be impacted due to their location on the site (e.g., piping cannot be impacted by liquefaction if it does not exist in the same location as liquefiable soils.)
	SFR-E2		Determine the parameters of interest for the appropriate failure mechanisms for the SEL items that may be impacted
SHA-H3			Determine the frequency of level of the hazard parameters of interest identified in SFR-E2 for nonflooding seismic hazards identified in SHA-H1 and not subsequently screened out
SHA-H4			For earthquake induced external flooding hazards identified in SHA-H1 and not screened out, satisfy the applicable requirements in XFHA in calculating the frequency of levels of the necessary hazard parameters
	SFR-E3		Determine the fragility for the SSCs based on the parameters of interest identified in SFR-E2
	SHA-H2		SHA-H2 Screening Step 3 – Remove failure of SEL items from secondary hazards from consideration based on failure frequency using the hazard curve and the fragility curve*
		SPR-E1/ SPR-E2	Quantification

*Once the fragility and hazard curves are developed, the information could be used directly in the quantification, rather than applying a second screening evaluation. This would eliminate the need for justification for "pruning" the model.

Table 5-A.2.1-10 Commentary to Supporting Requirements for HLR-SHA-I

Index No. SHA-I	Commentary
SHA-I1	Project documentation is the fundamental basis for reviews and users to understand. Guidance found in the SSHAC guidelines ([5-A-6], [5-A-7], [5-A-8]) should be consulted regarding expectations for this documentation: *(a)* the process used to develop PSHA inputs and perform PSHA computations *(b)* the data that were available and used in the evaluation process *(c)* the way in which the data, models, and methods of the larger technical community were integrated and considered in developing the PSHA inputs *(d)* the elements that make up the PSHA input model and their technical bases *(e)* the way in which uncertainties were modeled and quantified and how these capture the center, body, and range of technically defensible interpretations *(f)* the PSHA results and instructions for their use

Table 5-A.2.1-10 Commentary to Supporting Requirements for HLR-SHA-I (Cont'd)

Index No. SHA-I	Commentary
SHA-I2	The level of effort for developing PSHA documentation depends on whether and to what extent existing PSHA information is being used for the PSHA. For example, sites that use the seismic source model from NRC/DOE/EPRI [5-A-10] or the ground motion model from EPRI [5-A-3] can take advantage of the significant documentation available for those projects. For those sites where a new PSHA is performed, particularly for a SSHAC Level 3 PSHA, a significant effort may be necessary to develop adequate PSHA documentation. Guidance in NUREG- 2213 [5-A-6] and NUREG- 2117 [5-A-7] should be consulted regarding expectations for this documentation. It should be recognized by all parties involved in the PSHA study (sponsor, analyst, peer reviewer, fragility analyst, risk analyst, regulator, and members of the public) that expectations for developing adequate PSHA documentation can be a difficult and controversial issue. PSHA documentation is intended to make the PSHA tractable from process to inputs to results to sensitivities. In addition to the guidance above, to meet the expectations of SR SHA-I1(a) through SHA-I1(f), this documentation should *(a)* describe the roles and responsibilities of all project participants *(b)* provide sufficient information to understand which parts of the PSHA inputs (e.g., dominant seismic source, ground motion attenuation model) dominate the seismic hazard at the annual frequencies of exceedance important to the project *(c)* provide sufficient information showing the sensitivity of hazard results to the uncertainty in key parameters and variation in the hazard due to the changes in parameter values considered in the hazard assessment *(d)* provide sufficient tabulated data and data files that facilitate the ability to understand hazard inputs and to examine specific parameter assessments or scientific interpretations *(e)* document any peer review of the PSHA, including a summary of the whether the peer review was participatory and the comments and conclusions of the peer reviewers or panel While the PSHA documentation needs to meet the general expectations described above, the following specific PSHA results should be tabulated and provided with the final PSHA documentation to meet the state-of-practice for SR SHA-I1(f) and SR SHA-I1(h) through SHA-I1(j): *(a) A tabulated set of inputs for both seismic source models and ground motion models used with the PSHA*: The PSHA analyst is encouraged to review [5-A-6] and [5-A-7] and the expectations for developing a PSHA Hazard Input Document. The tabulated set of inputs should be supplemented with sufficient graphical information to display the seismic source and ground motion models inputs. If existing PSHA inputs are used and the documentation of these inputs is readily available in published reports, this information does not have to be repeated in the PSHA report for the site of interest. *(b) Seismic-hazard curves for horizontal ground motion for PGA and spectral frequencies*: A sufficient number of spectral frequencies should be used to enable robust determination and tabulation of uniform hazard response spectra (UHS). Mean and fractile (e.g., 5th, 15th, 50th, 85th, and 95th) hazard curves should be provided to clearly display the quantification of uncertainties. The seismic-hazard curves should represent the reference site condition associated with the ground motion model used for the PSHA. *(c) UHS at representative mean annual frequencies of exceedance such as* 10^{-3}, 10^{-4}, *and* 10^{-5}: If the UHS from the PSHA is insufficient to fully describe the spectral shape, the approach used to develop smoothed UHS should be documented along with a tabulated set of smoothed UHS for the representative mean annual frequencies of exceedance. *(d) Deaggregation of the hazard for an appropriate suite of distance and magnitude bins.* (See NUREG-2213 [5-A-6].) *(e) Vertical UHS including a tabulated set of V/H ground motion ratios if these are used to derive vertical ground motions for horizontal ground motions*: Deaggregation in terms of standard deviation will also be provided. *(f) As appropriate, input model used for site response analysis should include tabulated values of shear wave velocity, thickness, and density for all layers*: If multiple profiles are modeled this information should be provided for all profiles. Additional, tabulated values for all strain dependent properties should be provided for all layers including shear modulus and damping degradation with shear strain. *(g) As appropriate, input ground motions used to perform the site response analysis, including tabulated values of these motions*.

Table 5-A.2.1-10 Commentary to Supporting Requirements for HLR-SHA-I (Cont'd)

Index No. SHA-I	Commentary
SHA-I2 (Cont'd)	*(h) As appropriate, site amplification factors at each spectral frequency (and PGA) modeled in the site response analysis:* For each input motion, a tabulated set of mean and (log) standard deviations should be provided. *(i) Seismic-hazard curves and UHS for horizontal ground motion for PGA and spectral frequencies at the reference control point from the site response analysis*: The documentation should clearly describe the approach to deriving the seismic-hazard curves. *(j) Horizontal and vertical ground motion response spectra at the reference control point*: A tabulated set of values should be provided. *(k) As appropriate, for cases with multiple control points, foundation input response spectra at each control point*: A tabulated set of values should be provided. *(l) A tabulated set of any seismic-hazard curves if these are used for seismic risk quantification purposes.* *(m) Either in graphical or tabulated form, results displaying the most significant contributors to the seismic hazard at the site*: This assessment of significant contributors could include a consideration of the variance contribution for each of the major PSHA inputs to the total variance modeled in the PSHA.

5-A.2.2 Commentary to Seismic Fragility Analysis (SFR)

Fragility curves in an SPRA should capture the realistic seismic behavior of SSCs under a range of ground motion intensity levels without having either conservative or optimistic bias. This principle is consistent with the intent that an SPRA realistically estimates the seismic response of plant systems against a range of seismic scenarios. This response is affected by both shape and median-centered parameters of the fragility curve. In other words, a conservative or unrealistic estimation of median-centered ground motion parameter and variability in a fragility curve could mask individual SSCs that dominate SCDF and therefore lead to unreliable PRA insights.

Fragility curves are derived using the probability density functions of the seismic demand and capacity parameters. The log-normal function has been generally used to model the random variables related to a component's capacity and ground motion intensity, such as PGA or Sa. Even though other probability density functions can be used, the log-normal distribution has properties that facilitate the fragility analysis. Usually, the fragility curve is constructed by estimating a median ground motion acceleration A_m and logarithmic standard deviations for uncertainty β_U and randomness β_R.

The practice to develop fragilities in SPRAs for nuclear plants has been centered around six interrelated subjects: (*a*) definition of scope of fragility analysis, (*b*) building response analysis, (*c*) screening of SSCs, (*d*) plant walkdowns, (*e*) estimation of seismic-fragility parameters, and (*f*) documentation of the fragility analysis. The SRs for Seismic Fragility Analysis in Section 5-2.2 of Part 5 of this Standard are organized around these six core subjects.

The comments offered herein aim to provide a background on the theory and practice that contributed to developing of each requirement. In addition, practical scenarios are provided to enhance the understanding and the effort required for compliance with the requirements.

Table 5-A.2.2-1 Commentary to High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Seismic Fragility Analysis (SFR)

Designator	Commentary
HLR-SFR-A	The scope of the Seismic Fragility Analysis is typically defined in the form of a SEL. This list generally includes identification of the SSCs that are credited in an SPRA and their descriptions, building locations (building, floor, and room number), failure modes of interest, and plant systems.
HLR-SFR-B	This requirement addresses the need to provide seismic response parameters such as displacements and in-structure accelerations that represent a realistic estimate of failure level of SSCs. This requirement is of utmost importance in an SPRA as strong judgment should be exercised by the engineer in order to define the appropriate level of ground input to justify failure of SSCs across a spectrum of seismic initiating events. This evaluation needs to be done in accordance with site-specific hazard and plant structural response characteristics.
HLR-SFR-C	Screening allows the analyst to focus resources on areas in an SPRA that drive the plant-risk levels.
HLR-SFR-D	Fragilities of SSCs in an SPRA should represent as-built and as-operated conditions. The accepted practice to achieve this requirement is through plant walkdowns. For more than 40 years, experience has shown that plant walkdowns provide the SPRA team with the practical sense of seismic ruggedness in the plant as well as the identification of credible seismic-induced failure mode(s) of the SSCs often missed from review of design data (i.e., drawings or computer visualization models).
HLR-SFR-E	This requirement focuses on the mathematical approach used to establish the parameters defining the seismic-fragility curve of SSCs. The fragility analyst should ensure that the variability and median values associated with variables affecting capacity and demand of SSCs are representative of the seismic-induced failure directly leading to the failure mode of importance to the SPRA.
HLR-SFR-F	Although SPRA is developed as a snapshot in time, its use is intended for future risk-informed programs by several users across different fields of expertise. Thus, it is imperative to document the fragility analysis in a manner that facilitates peer reviews and future updates/upgrades.

Table 5-A.2.2-2 Commentary to Supporting Requirements for HLR-SFR-A

Index No. SFR-A	Commentary
SFR-A1	In an SPRA, it is customary for the systems analyst to define the initial list of SSCs for fragility analysis. This list generally includes failure modes of interest (e.g., loss of operability or failure of pressure boundary), building location of component, and component description. Therefore, the fragility analyst is expected to perform a fragility assessment, whether by calculation or judgment, and provide the analysis for the SSCs and relevant failure modes defined by the systems analyst in the SEL. The importance of SR SFR-A1 stems from the need to ensure consistency between the failure modes defined by the systems analyst in the SPRA and the results of the fragility analysis. In the context of fragility analysis, the term "failure mechanism" refers to the seismic-induced failure of a component that leads to the failure mode defined by the systems analyst. Failure of valves provides a good example of this mechanism-mode relationship: first, the systems analyst defines the failure mode as the valve failing to open on demand, whereas the seismic-fragility analyst then defines the failure mechanism induced by an earthquake to result in such a failure mode as either excessive binding of the valve yoke or malfunction of the operator. Experience has shown that the number of SSCs for which fragilities are required will most likely vary throughout the duration of the SPRA project. For example, new SSCs may be added to the scope of work, resulting from walkdown observations. On the other hand, there could be instances where the initial SEL is reduced because SSCs are no longer credited in the SPRA model. It is recommended to document how the scope of fragility calculations evolves throughout the SPRA project.

Table 5-A.2.2-2 Commentary to Supporting Requirements for HLR-SFR-A (Cont'd)

Index No. SFR-A	Commentary
SFR-A2	This SR ensures that relationships between failure probabilities of individual SSCs are appropriately modeled in the SPRA. Two SSCs are independent if the probability of both failing together is the product of their individual failure probabilities. When failures of two SSCs are not independent, then the two SSCs are said to be dependent. The relationship between the two SSCs underlying this dependency could be causal (i.e., failure of one SSC triggers the failure of the other—for example, a component mounted in a structure, where collapse of the structure causes failure of the component) or otherwise, and this relationship should be represented in the plant-response model. Causal dependencies are usually directly represented in the plant-response model through appropriate logic gates. Noncausal dependencies may be represented in the plant-response model through some combination of systems logic, grouping, and fragility correlation. Fragility correlation is a dependency between two SSCs' ground motion capacities that can be represented by a linear relationship. Perfect correlation between two SSC fragilities occurs when the SSC ground motion capacities (i.e., a random variable whose cumulative distribution function is usually defined by a double-log-normal curve and the fragility parameters median ground motion capacity, logarithmic standard deviation for randomness, and logarithmic standard deviation for uncertainty) are linearly proportional. As such, for perfectly correlated SSCs, the conditional probability of failure of one SSC given the failure of the other is higher than its original (unconditional) failure probability. SSCs with uncorrelated fragilities have no linear dependence between their ground motion capacities, and knowledge about failure of one SSC does not inform the failure probability of the other. Many situations occur somewhere between these two extremes, wherein a partial correlation is said to exist between the two fragilities. Current SPRA practice idealizes partial correlations as either perfectly correlated or uncorrelated, whichever of the two is more appropriate (a rigorous treatment of partial correlations is presented in NUREG/CR-7237 [5-A-17]). The determination of whether two or more SSCs' fragilities are correlated and the degree of correlation requires a comparison of *(a)* seismic demands associated with the SSC failure mechanisms (acceleration demands due to seismic shaking, displacement demands in case of seismic spatial interaction, etc.) *(b)* seismic capacity associated with the SSC failure mechanism (relay chatter acceleration capacity, anchor capacity, etc.) SSCs of similar construction (e.g., equipment type, materials, physical configuration), installed in a similar fashion (e.g., directional orientation, anchorage type), and located near each other (e.g., in the same area, floor, and building) are expected to have similar failure mechanisms, seismic demands, failure modes, and seismic capacities. As such, the seismic fragilities for these SSCs are typically modeled as perfectly correlated. Consequently, information pertinent to similarity among component construction, installation, and location should be reviewed and included in the basis for decisions regarding fragility correlation in the systems-risk model. However, determining the appropriate idealization (uncorrelated or perfectly correlated) may not be straightforward in many cases. Consider two dissimilar SSCs with similar dominant frequencies located next to each other. If the seismic-fragility variabilities of the two SSCs are almost completely dominated by variability in the seismic demands (e.g., due to large variability in the soil properties underlying the building) and the difference in the seismic capacities associated with the failure mechanisms (which may or may not be similar) is small, then significant partial correlation may exist between the two SSC fragilities. Communication between the fragility and systems analysts is important in such situations to ascertain the appropriate modeling idealization: for example, if modeling the two SSCs as uncorrelated produces conservative risk results with negligible impact on the overall risk insights (as determined from sensitivity analyses), it may be appropriate to ignore the nontrivial partial correlation between the two SSCs.

Table 5-A.2.2-3 Commentary to Supporting Requirements for HLR-SFR-B

Index No. SFR-B	Commentary
SFR-B1	The relationship between structure response and amplitude of seismic input motion is inherently nonlinear across the range of accelerations considered in an SPRA. SPRAs are often quantified for Sa or PGA ranging from 0g to 5g or greater. Due to the nonlinear nature of soil and structure behavior, the response at any given acceleration in this range will be a function of both the input ground motion and its effect on the nonlinear characteristics of the system. Ideally, structure response analyses would be performed at several different input levels to determine the varying seismic demands on SSCs across the full range of ground motion levels for which the probability of failure of any credited SSC contributes to overall risk. In practice, however, some simplification is generally warranted. Therefore, an elastic structure response analysis is typically performed to develop in-structure response spectra (ISRS) for one input level, defined by the Reference Earthquake (RE), and the ISRS is linearly scaled to other input levels as a simplifying approximation. The intent of this SR is to ensure that the seismic demands used in fragility analysis (HLR-SFR-E), including any corresponding simplifications, are sufficiently realistic (or conservative for CC-I) to not significantly bias the overall SPRA results and risk insights. Many different response-analysis approaches could potentially meet this intent, and this Nonmandatory Appendix does not endorse any one approach as preferred over any other. Rather, the commentary below outlines several elements that should be considered and briefly describes an approach that has been used in past SPRAs to meet the intent of SR SFR-B1. The following elements should be considered in the seismic response analysis to ensure adequate realism: *(a) Nonlinearity in seismic response with increasing ground motion input levels* (e.g., closing of gaps, building-to-building interaction, strain-compatible soil properties, degradation effects such as concrete cracking, steel yielding, increased damping, reduced stiffness): Potential nonlinear effects should be identified, and nonlinearities that are found to have a significant effect on the SPRA results should be directly addressed in the SPRA. *(b) RE or Hazard Range of Interest (HROI):* The specific (or range of) ground motion levels for which SPRA results and risk insights are most sensitive to seismic demands on SSCs should be identified and understood to inform the selection of analysis simplifications for seismic response analysis. The range of ground motion levels should be selected and used such that it does not introduce significant bias in the SPRA results. *(c) The response spectrum shape used to define seismic input to the response analysis:* In general, the UHS shape will differ somewhat at different ground motion input levels. The shape of the input response spectra should be defined to ensure it does not introduce significant bias in the SPRA results. *(d) The ground motion reference parameter (e.g., PGA or Sa and control point:* Most SPRAs express fragilities in terms of PGA at a specific control point (e.g., at the ground surface, top of rock, basemat of the reactor building), and then the risk quantification convolves the fragilities with the PGA hazard defined at the same control point. It can also be acceptable, and sometimes preferred, to express fragilities in other terms, such as the average ground Sa over an important frequency range. Whatever parameter and control point is selected, they must be used consistently throughout the SPRA within the Seismic Hazard Analysis, Seismic Fragility Analysis, and Seismic Plant Response Analysis technical elements. *(e) Input time histories:* SPRAs typically use time history analysis to develop ISRS for input to equipment seismic fragilities. The input ground motion time histories must be selected, developed, and/or conditioned in such a way to preclude introducing significant bias into the SPRA results. Further discussion is provided below on these elements as they pertain to meeting the intent of SR SFR-B1.

Table 5-A.2.2-3 Commentary to Supporting Requirements for HLR-SFR-B (Cont'd)

Index No. SFR-B	Commentary
SFR-B1 (Cont'd)	Structure response analyses in SPRAs to date have typically been performed at a single input level and then linearly scaled to estimate responses at other levels. To minimize bias introduced by this linear approximation, the analyses are performed using soil/structure properties (stiffness and damping) and nonlinear behavior (e.g., boundary conditions, building-to-building interaction) corresponding to an RE ground motion input (spectrum shape and level). The RE should be selected carefully and subsequently validated when following this simplified approach to structural response analyses. One reasonable approach for selecting an RE is as follows: *(a)* Estimate one or both of the following based on available information prior to performing seismic response analyses: *(1)* Estimate the SCDF and SLERF based on the best available information prior to performing the SPRA. The estimate should consider the seismic design criteria, prior SPRA (site specific or from similar plants), and the latest site-specific seismic-hazard estimate relative to prior hazard estimates. *(2)* Estimate a plant-level fragility for core damage and large early release based on the best available information prior to performing the SPRA. The plant-level fragility is the conditional probability of the damage state as a function of input level (e.g., the SCDF plant-level fragility is the conditional core damage probability as a function of input level). The fragility estimate should consider the seismic design criteria, past evaluations (Seismic Margin Assessment, Systematic Evaluation Program, Individual Plant Examination of External Events, Expedited Seismic Evaluation Process, etc.) and the latest hazard. Based on experience, logarithmic standard deviations (β) for a plant-level fragility are typically in the range of 0.3 to 0.5. *(b)* Convolve the plant-level fragility (or candidate fragilities) with the site-specific seismic hazard to estimate the seismic risk (SCDF and/or SLERF). The convolution is typically performed by numerical integration. Trial-and-error iterative approaches can be used to test candidate seismic fragilities and/or seismic risks, depending on choice of *(a)(1)* and *(a)(2)* above and available information, to arrive at an RE definition considering all site-specific insights. The resulting risk and/or fragility will necessarily depend on the judgment of the engineer and should be validated and potentially adjusted as the SPRA progresses. *(c)* Inspect the convolution results across the range of input levels considered and use this information to identify the input level that contributes most significantly to seismic risk. The significance of risk contribution from various input levels can be judged several ways, such as the following examples: *(1)* the level at which the cumulative risk (SCDF or SLERF) reaches 50% of the total *(2)* the level where the integrand of the convolution integral is maximized (the integrand can be considered a "risk density") *(3)* the level where the slope of the plant-level fragility curve is greatest *(d)* Select a UHS with an Annual Exceedance Frequency that is reasonably aligned with the dominant input level. The UHS selected is the RE. Conventionally, the RE is selected as either the 1.0E-4 or 1.0E-5 UHS. If the dominant input level lies between the 1.0E-4 and 1.0E-5 UHS, then the RE is often instead defined as the Ground Motion Response Spectrum per ASCE 4-16 [5-A-18]. For very low-hazard and/or seismically robust plants, the dominant input level could be closer to the 1.0E-6 UHS. *(e)* As initial SPRA results become available, the risk-dominant input level should be evaluated to assess whether it is reasonably aligned with the RE. If it is anticipated that the final SPRA results will show significant misalignment between the dominant input level and the RE, then the effect of the misalignment should be evaluated. Examples where the SPRA results may motivate potential adjustment to the RE selection and/or potential extension or enhancement of the structure response analyses include the following: *(1)* *Existence of low-capacity/high-importance SSCs*: In these cases, the RE may be at a higher ground motion than the failure level of such SSCs, such that the estimated fragility of these SSCs could be unrealistic. *(2)* *Existence of high-capacity/high-importance SSCs*: In these cases, the RE may be at a lower ground motion than the failure level of such SSCs, such that the estimated fragility for these SSCs could be unrealistic. *(3)* *Broad range of risk contribution*: In these cases, the seismic risk may be governed by a wide range of relatively equally significant SSC fragilities, such that the selection of a single RE may not be representative of the risk contribution for each.

Table 5-A.2.2-3 Commentary to Supporting Requirements for HLR-SFR-B (Cont'd)

Index No. SFR-B	Commentary
SFR-B1 (Cont'd)	(4) *Low hazard and/or robust plant*: In these cases, the SSC fragilities can be sufficiently high such that meaningful probability of failure coincides only with extremely rare earthquakes, and risk contribution can end up "smeared" across a wide range of large ground motion levels. (5) *Nonlinear "cliff-edge" effects*: In these cases, use of an RE defined at a ground motion level lower than the initiation of significant nonlinear effects resulting in SSC fragilities greater than this level could be unrealistic. Examples include building-to-building impact, nuclear steam supply system (NSSS) support conditions in a pressurized water reactor, onset of foundation sliding, and others. Once the RE or HROI selection is made, then other technical decisions related to the topics introduced earlier in this text may follow, as discussed in the paragraphs below. If an alternative simplification for seismic response analysis is taken (i.e., rather than a single RE/HROI), then similar (but perhaps broader) decisions should still be made, with the following discussion still relevant. The RE selection defines the degradation levels (e.g., strain-compatible soil properties, building modeling parameters such as stiffness and damping, contact when gaps close) used in seismic response analyses. Structure and soil properties tend to degrade when subjected to higher levels of ground motion. In some beyond-design-basis events, the behavior of the soil-structure system will be dominated by nonlinear soil effects and/or significant concrete cracking. Therefore, modeling inputs used in the seismic response should correspond to the level of structure and soil material degradation expected for the RE level and spectral shape. SR SFR-B1 requires that the RE shape, input level, and corresponding degradation states of soil and building models do not introduce significant error or bias in the SPRA results. Another important aspect of SR SFR-B1 is the selection of the ground motion reference parameter (e.g., PGA or Sa) and control point used in the convolution of fragilities and the plant seismic-hazard curve. The two common ground motion parameters used in SPRAs are the PGA and average Sa. Average Sa is considered a good indicator of earthquake damaging effects and is sometimes preferred as the ground motion parameter for fragility analysis. However, PGA has historically been used in more SPRAs and therefore may be more familiar to the hazard, fragility, and systems engineers. It is essential, however, that whichever parameter is chosen, it be used consistently throughout the SPRA process. Similarly, the seismic-hazard curves, RE ground motion, and fragilities must be defined at a common control point that is used consistently in the response analysis, fragility analysis, and risk quantification. It would be erroneous, for example, to express fragilities in terms of the PGA at the ground surface and then to convolve them with PGA hazard curves defined at a control point at depth within the underlying soil/rock. When input to seismic response analyses is defined by time histories, the time histories should be developed to be consistent with the selected ground motion input level, control point, and spectral shape. Several industry guidance documents provide guidance for creating artificial time histories and/or selecting and conditioning natural seeds. For example, ASCE 4-16 [5-A-18] provides design criteria for time history matching. The guidance and commentary in the industry literature should be considered when developing time histories to ensure and justify that the time histories used in the response analysis do not introduce significant error or bias into the SPRA results. SR SFR-B1 uses different action verbs for CC-I (ESTIMATE) and CC-II (CALCULATE). Here, it is important to distinguish between "estimated response" and "calculated response." In general, an estimated response is that in which a rigorous analytical process is avoided by relying on the judgment of the engineer or simplistic mathematical approximations. Typically, estimated responses will be somewhat conservatively biased. In the context of SR SFR-B1, a typical example of an "estimated" response could be when in-structure response of one building is used for another similar building. Another common example is when approximate RE ISRS is estimated by scaling design ISRS. SR SFR-B1 permits the use of estimated responses in CC-I for all SSCs, whereas for CC-II, calculated responses are required for risk-significant SSCs such that the approximations do not significantly bias the SPRA results or risk insights. In summary, SR SFR-B1 requires that the seismic response analysis be sufficiently realistic (or appropriately conservative) such that any approximations introduced do not significantly bias or alter the SPRA results or risk insights. A few key elements that should be considered are nonlinearity in response with increasing input levels, the definition of the site-specific input spectral shape and input level (e.g., RE), the reference parameter and control point, and development of input time histories. This list of key elements is not intended to be an exhaustive list, as there are many more considerations in developing realistic seismic response. SR SFR-B2, SR SFR-B3, SR SFR-B4, SR SFR-B5, and SR SFR-B6 focus on several other elements of the seismic response analysis that are required to obtain sufficiently realistic (or appropriately conservative) seismic response.

Table 5-A.2.2-3 Commentary to Supporting Requirements for HLR-SFR-B (Cont'd)

Index No. SFR-B	Commentary
SFR-B2	The scaling procedures given in EPRI NP-6041 [5-A-19] and EPRI 3002012994 [5-A-16] may be used. Scaling of existing ISRS should consider the shapes of the original and new ground motion spectra, structural natural frequencies, mode shapes, and participation factors. Justification needs to be provided if there are significant differences in the phenomena that may be inadequately represented by linearly scaling responses, including structural dynamic characteristics between the original model and the current configuration, foundation characteristics (e.g., nonlinear soil properties), and ground motion spectra. There is an important distinction between the "scaling" mentioned in SR SFR-B1 ("provide a basis for scaling response from one ground motion level to another") and SR SFR-B2 ("If scaling of existing response analysis is used . . ."). The former refers to an approximation in which structure response analysis is performed for one ground motion level (i.e., the RE), and then responses at other levels are treated as linearly proportional to ground motion level (e.g., a twofold increase in input is treated as producing an approximately twofold increase in response). The latter refers to a more general approximation in which response to a new ground motion spectrum is scaled from an analysis that used a different ground motion spectrum. In this latter, more general case, the change in response is affected not only by the amplitude of the seismic input but also by the change in shape of the input spectra, structural dynamic characteristics, and so on.
SFR-B3	The adequacy of building models for use in SPRA will depend on their ability to capture the realistic response of their as-built, as-operated condition. Important modeling features affecting seismic response include equipment masses, dynamic coupling of secondary systems, floor diaphragm flexibility, soil embedment, floor torsional effects, sloshing, directional coupling, rotational inertia, and torsional effects. Caution should be exercised when reusing older (e.g., design-basis) building models as important modeling details may have been defined with obsolete methods or conservative bias. Conservative biases would lead to a misrepresentation of the structural dynamic response. Structural modeling parameters with large sources of uncertainty should also be considered in an SPRA. These modeling parameters include, for example, structural damping and stiffness modifiers consistent with the response behaviors exhibited at the selected ground motion level as required in SR SFR-B1. Experience has shown that the effort to achieve realistic estimates of building-modeling properties could require considerable analytical and computer time, thus incurring excessive project resources. To this end, structural analysts should maintain a balanced philosophy between the interim objective of achieving reasonable estimates of median modeling features and the overall goal of achieving reliable PRA results for future risk-informed decisions. The structural modeling approach can be considered as a source of model uncertainty and the effects of the modeling assumptions would need to be justified on the risk-informed decision being made.
SFR-B4	EPRI 3002012994 [5-A-16] provides guidance for determining median-centered seismic response and its variability due to randomness and uncertainty in the various parameters affecting seismic response. Variability in the various parameters could also be estimated based on available test data with appropriate justification. This SR requires the estimation of the variability in the best-estimate response. The variability can be expressed as "composite" or separately as aleatory and epistemic.

Table 5-A.2.2-3 Commentary to Supporting Requirements for HLR-SFR-B (Cont'd)

Index No. SFR-B	Commentary
SFR-B5	SSI effects could be significant for certain sites based on the site soil conditions, construction configuration, and/or structural properties. The potential effect of SSI and the subsequent decision for whether SSI is considered or not should be assessed and documented. If SSI effects are considered to be significant, ASCE 4-16 [5-A-18] and EPRI 3002012994 [5-A-16] provide guidelines for performing SSI analysis, including treatment of variabilities. Guidance is available [5-A-20] for conditions where SSI effects may not need to be considered, such as for rock sites. However, for rock sites, the effects of spatial incoherence of seismic ground motion could be significant and should be considered. Ground motion incoherence typically lowers the structural response at higher frequencies (>10 Hz) while it typically increases rocking and torsion response. The distinction between CC-I and CC-II is twofold. First, CC-I does not specifically require SSI effects to be considered, whereas CC-II requires them to be considered if they are significant to structural response. Second, the level of rigor required when considering SSI effects is higher for CC-II than for CC-I. For example, for CC-I applications, a simplified stick model with soil springs may be sufficient to estimate SSI response, whereas for CC-II applications, a more detailed analysis accounting for the embedment effects, incoherency, and so on may be necessary to calculate SSI response. Additionally, for CC-I applications, it may be sufficient to use approximate soil properties based on a nearby facility or a site with similar materials (e.g., as long as they are reasonable and appropriate for the geotechnical materials and hazard level for the site in question), whereas CC-II applications require the use of soil properties from site-specific geotechnical characterization with specific strain compatibility to the hazard level(s) considered. Either deterministic or probabilistic SSI analyses can be performed. As soil properties (shear wave velocity, damping, etc.) are strain dependent, soil properties for SSI should be consistent with the site seismic-hazard level defined in SR SFR-B1. Variability in soil properties needs to be considered. Whenever possible, it is preferred for variability in soil properties considered for SSI to be defined consistently with the variability in soil properties considered in site response analysis as part of PSHA. These variabilities should be propagated through the SSI analyses so that their effects on the structure response can be quantified. Quantification of the effect of variabilities can be reported in various forms, including as estimates of both median and some fractile (e.g., 84th percentile) of response or as measures of structural response variability (e.g., coefficient of variation, logarithmic standard deviation) directly.
SFR-B6	The probabilistic response analysis requires a sufficient number of simulations to be able to rigorously quantify the aleatory and epistemic variabilities in the free-field ground motion, the building and foundation media stiffness, damping values, and so on. The treatment of the aleatory variabilities can be accomplished through the collection of ensembles of ground motion time history sets, preferably obtained from an earthquake catalogue of recorded motions. Each of the input-motion sets shall consist of two horizontal components and one vertical component. These time histories should be compatible with the seismic hazard (e.g., UHS) at the appropriate control point. Epistemic variabilities quantify uncertainty in the behavior of the soil-structure system, such as uncertainty in soil shear modulus, soil material damping, and the structure dynamic characteristics. Uncertainty in the structural dynamic characteristics is typically addressed by varying the structure fixed-base frequencies and modal damping. The probability distribution function can be derived by various methods of sampling, including Latin Hypercube Simulation. The analyst must ensure that a sufficient number of simulations are performed to achieve stable probabilistic distributions for the response parameters. For example, a sensitivity study conducted by EPRI [5-A-21] demonstrated that the use of 30 Latin Hypercube simulations was sufficient to yield stable median values and logarithmic standard deviations of selected response quantities. Additional guidance on the number of simulations is provided in ASCE 4-16 [5-A-18]. The probabilistic seismic response analyses performed in the early days would require generation of 30 sets of time histories for the input ground motions, which were defined by the median and 84th percentile Ground Response Spectra (GRS). The 84th percentile GRS was used to account for uncertainty in the spectral shape (so-called peak-to-valley variability). The 30 sets of time histories were adjusted so that their median and 84th percentile GRS would closely match the corresponding GRS. The other response variables explicitly considered in the probabilistic response analyses were structure stiffness and damping and soil shear modulus and material damping. Thus, from the resulting statistically calculated median and 84th percentile ISRS, one could obtain a composite variability for response due to variability associated with the input ground motion, the structure model, and the soils. Refer to EPRI Report 3002012994, Appendix H [5-A-16] for historical context for why such peak-to-valley variability is no longer explicitly included in seismic response analysis.

Table 5-A.2.2-4 Commentary to Supporting Requirements for HLR-SFR-C

Index No. SFR-C	Commentary
SFR-C1	The term "inherently rugged" refers to seismic capacities well beyond the capacities of SSCs that normally govern seismic risk. As such, there is very high confidence that inherently rugged SSCs will not significantly contribute to seismic risk, regardless of the site-specific seismic-hazard level. Typical items include manual valves, check valves, and small, in-line strainers. The EPRI SPID [5-A-20] and EPRI Report 3002012994 [5-A-16] include extensive discussions on the meaning of "inherently rugged," as well as a list of types of SSCs that are typically considered inherently rugged. This SR requires specifying the basis used for defining the list of what are considered as inherently rugged components, which in general should be regardless of the site seismicity. In practice, there could be scenarios where fragility analysts may want to expand the available generic lists of inherently rugged component types (e.g., provided in the EPRI SPRAIG [5-A-22]) with the intent to screen a larger set of SSCs from inclusion in the systems model and risk quantification. For example, it is commonly acceptable to categorize manual valves as inherently rugged components without developing an explicit, rigorous justification for their seismic ruggedness. However, fragility analysts may judge other nonconventional SSC types (e.g., other than those listed in SPID [5-A-20]) as inherently rugged, such as small pumps, motor operated valves, air operated valves, or wall mounted instruments. In this case, plant-specific justification should be provided to demonstrate that the additional SSCs identified as inherently rugged have sufficiently high capacities relative to other SSCs in the SEL to warrant screening them out from the systems model and quantification. A similar example exists where certain SSCs have sufficiently low seismic demands (as opposed to sufficiently high capacities) relative to other SSCs in the SEL to warrant screening them out from the systems model, such as when a portion of the plant is seismically isolated, effectively reducing the seismic demand on SSCs supported "above" the isolators.
SFR-C2	The fragility analysis in an SPRA should focus project resources on SSCs that are important to plant risk. A fragility threshold level is first established by the systems analyst (as required in SR SPR-B5) in terms of a ground motion parameter (e.g., PGA or Sa). The fragility analyst will then compare capacities of SSCs in the SEL (also expressed in terms of the reference ground motion parameter) with the fragility threshold level. This SR requires that the SPRA provide the basis and methodology employed for developing the methodology used to compare the SSC capacities with the fragility threshold level. Guidance that can be used for establishing the basis for the fragility threshold is provided in various documents for developing seismic capacities of SSCs after satisfying specific caveats. For example, EPRI 3002012994 [5-A-16] and EPRI NP-6041-SL [5-A-19] provide generic fragility screening-level seismic capacities as well as guidance on how to justify that SSCs meet the fragility-screening levels. This approach can be used to satisfy this SR provided that the generic screening-level capacities are high enough to meet the fragility threshold established by the systems analyst (SR SPR-B5). However, the fragility threshold level (SR SPR-B5) in high-seismicity sites may be higher than the generic screening-level capacities provided in EPRI 3002012994 [5-A-16] and EPRI NP-6041-SL [5-A-19]. For these cases, the analyst should develop and justify alternate criteria to establish seismic capacities for comparison with the higher fragility threshold level (SR SPR-B5). The capacities could be based on a combination of use of the site seismic design criteria, site-specific test data, and bounding analyses.

Table 5-A.2.2-5 Commentary to Supporting Requirements for HLR-SFR-D

Index No. SFR-D	Commentary
SFR-D1	It is important to note the difference between the intent of SR SFR-C2 and SR SFR-D1. First, SR SFR-C2 requires the fragility analyst to clearly document the basis for screening components by using industry-accepted methodologies, these being, for example, past experience data, judgment of the engineer, or conservative/generic capacity values. On the other hand, SR SFR-D1 is more SSC specific in the sense that it requires a clear identification of those SSCs that meet the fragility threshold provided in SR SFR-C2. SR SFR-D1 also includes the requirement to ensure that anchorage or structural supporting condition of the component also meets the fragility threshold. Thus, both functional and structural-related failure modes are assessed in the screening process. The fragility threshold criteria defined in HLR-SFR-C are applicable to SR SFR-D5, SR SFR-D6, and SR SFR-D7.
SFR-D2	The purpose of the SPRA walkdown is to verify that the component fragility curves are consistent with the current plant configuration. The SPRA walkdown is vital to confirming screening applicability (SR SFR-D1), collecting information necessary for fragility calculations, and identifying anchorage and interaction concerns. Ideally, the walkdown team includes adequate experience to make appropriate judgments concerning credible failure mechanisms, potentially significant interactions, and information potentially significant to fragility calculations. When determining the scope and details of the walkdown, it is important that the intent of the walkdown be considered. The intent is to identify items that invalidate modeling in the PRA to such an extent that the model does not reasonably represent the as-built, as-operated plant. In keeping with this intent, it is acceptable that conditions that can be justified as not likely to affect the results (i.e., will not change the risk profile or insights) do not need to be validated. As such, and per Inquiry 20-2435 [5-A-26], it is not required that 100% walkdown be performed if adequate justification can be provided that a lesser scope will suffice. Various justifications could be considered valid, but they must show that *(a)* items that could have a significant impact were walked down and *(b)* those items not walked down could not have a significant impact. The following are examples of possible justifications: *(a)* *Bounding Risk Impact:* If the importance measure of an item is low, such that even if the item were assumed failed all the time, the PRA results would not meaningfully change. *(b)* *Adequacy of Documentation:* There is a sufficient weight of evidence, through drawings, photos/videos, analyses, or interviews with knowledgeable plant staff, that the conditions are as assumed in the PRA. *(c)* *Impact of Possible Discoveries:* Given past experience with the types of deviations typically found during walkdowns, it is not credible or likely that a deviation would be found that could affect the conditions assumed in the PRA to the extent required to meaningfully change the results.

Table 5-A.2.2-5 Commentary to Supporting Requirements for HLR-SFR-D (Cont'd)

Index No. SFR-D	Commentary
SFR-D3	In the context of fragility, a seismic vulnerability is defined as any failure mechanism for an SSC, which could control the seismic capacity in the fragility analysis of that SSC. In addition to review of design documents, the identification of seismic vulnerabilities involves detailed plant walkdowns by engineers knowledgeable in seismic performance of SSCs, their design functions, and their critical failure mechanisms. Examples of seismic vulnerabilities include weaknesses in the anchorage load path, excess flexibility in the attachment and load path of internal subassemblies (which may lead to sensitivity to low frequency or vertical direction seismic input), insufficient commodity clearance, differential displacement issues, overhead seismic interaction falling hazards, and poor plant maintenance that may have an impact on component functionality. The focus of CC-I is to identify seismic vulnerabilities so that the assumptions and the use of generic seismic fragilities are conservative. For example, if seismic-experience-based generic capacity is intended to be used for an air-handling unit, then the walkdown should ensure that all potential vulnerabilities that may result in capacity less than the generic capacity are identified. This evaluation process should not only verify compliance with the applicable experience-based caveats and inclusion rules but also verify that all potential seismic interactions, such as potential falling of masonry walls, have capacities exceeding the seismic-experience-based capacity that will be assigned to that air handling unit. The focus of CC-II is to identify seismic vulnerabilities so that the seismic-fragility calculations can be realistic and plant specific as needed. It is critical that all seismic vulnerabilities that may control seismic fragility are captured during the walkdown and carried through to the fragility analysis and that the identification of seismic vulnerabilities be thorough and realistic. At the time of the walkdown, excess conservatism cannot be arbitrarily used because it is typically not known yet if the component is going to be a dominant contributor to plant risk. The walkdown should realistically identify the seismic vulnerabilities appropriate for each SSC. For example, consider that a component vulnerable to impact may be within close proximity to a poorly anchored heat exchanger. However, the configuration of floor penetrations associated with the heat exchanger and attached piping may preclude the heat exchanger from deflecting toward and reaching the component. In this case, the proximity to the heat exchanger is not a realistic seismic vulnerability for that component. If the fragility analysis were incorrectly governed by the capacity of the heat exchanger, then that low-capacity fragility would not be realistic and may mask the SPRA from identifying true plant vulnerabilities. Conversely, as a second example, consider an electrical cabinet with seismic capacity verified by shake-table fragility testing in close proximity to a tall masonry wall with seismic capacity higher than the capacity of the cabinet. However, prior to experiencing seismic motion consistent with the seismic capacity level of the electrical cabinet, the masonry wall may deflect out of plane and strike the electrical cabinet with enough force such that functionality of the cabinet is lost. If the deflection of the masonry wall is not identified as a vulnerability during walkdown, then the fragility analysis may significantly overestimate the seismic capacity of the electrical cabinet.
SFR-D4	Here the term "failure mechanism" refers to the seismically induced failure of interest in a fragility calculation such as pullout of anchors, excessive bending of a valve yoke, or circuit burnout in cabinets.
SFR-D5	No commentary provided.
SFR-D6	No commentary provided.
SFR-D7	During a walkdown, the walkdown team may observe hundreds of credible seismic interactions. For example, two adjacent conduits may impact each other during an earthquake. However, the earthquake experience data have shown that these types of interactions do not pose a risk to the intended plant-safety functions. Thus, the walkdown team must exercise judgment as to when a credible interaction may be risk significant and warrant further evaluation. Guidance is available in EPRI NP-6041-SL [5-A-19] and the SQUG GIP [5-A-23]. Seismic interactions that may affect SSCs intended functions or operator actions include proximity impacts (e.g., impact between cabinets), falling hazards (e.g., failure and falling of nonseismically designed SSCs and masonry walls), and differential displacements (e.g., differential building displacements).

Table 5-A.2.2-6 Commentary to Supporting Requirements for HLR-SFR-E

Index No. SFR-E	Commentary
SFR-E1	This SR requires the identification of relevant seismically induced failure mechanisms of structures, equipment, and soil. These failure mechanisms become the focus for fragility calculations performed in SR SFR-E2. The failure mechanisms evaluated in the fragility calculations should be related to the credited SSC functions in the SPRA model. For example, equipment anchorage failure modes are evaluated because they can lead to functional failures in the equipment. Interaction failure modes such as block wall failures near SEL equipment should be evaluated if the interaction would prevent the equipment from performing its credited function. SR SFR-E1 involves the identification of relevant and realistic failure modes of structures, equipment, and soil. For structures, typical failure mechanisms include sliding, overturning, yielding, and excessive drift. For equipment, typical failure mechanisms include anchorage failure, functional failure, impact with adjacent equipment or structures, and bracing failures. For soils, typical failure mechanisms include liquefaction, slope instability, and excessive differential settlement. In CC-I, failure mechanisms can be identified in a less rigorous manner than CC-II. The CC-I evaluation may take the form of identifying the most likely failure mechanism for a given SSC, whereas for CC-II it may be necessary to identify more than one likely failure mechanism to consider in the SSC fragility calculation. This SR allows the use of a conservative failure mechanism to establish the fragility parameters at the component level; however, the fragility analyst needs to have a proper understanding about the components' dependency. For example, the intent of the "rule of the box" for equipment is that all of the components mounted on or in this equipment are considered to be part of that equipment and do not have to be evaluated separately. The fragility analyst can identify the "rule of the box" components; however, auxiliary components that are not mounted on the equipment but are needed by the equipment to fulfill its intended function need to be evaluated separately. The fragility analyst can gather information about the dependency from the system engineers or by reviewing the plant drawings (e.g., piping and instrument drawings, single-line electrical, anchorage drawings, walkdown notes). This scope may include sections of piping, cable trays, or supports that are not part of the failure mechanism but can impact the other components. Another example is the LOOP with the typical generic fragility parameters, which allows exclusion of the fragilities for components that are dependent on off-site power at median 0.3g earthquake or greater. However, fragilities for components that are dependent on off-site power at lower than 0.3g median earthquake need to be developed. The fragility analyst needs to identify and include any correlation with a redundant component. Correlation may depend on component characteristics, physical separation, and location within the plant. The correlation, dependency, and failure mechanism may be used for combining SSCs into groups, which reduces the number of fragilities used in the plant-response model. The term "risk significant" is defined in Section 1-1.9 of this Standard. In general, in the context of fragility analysis, "risk significant" generally refers to SSCs that significantly contribute to SCDF and/or SLERF.

Table 5-A.2.2-6 Commentary to Supporting Requirements for HLR-SFR-E (Cont'd)

Index No. SFR-E	Commentary
SFR-E2	Realistic and site-specific fragilities are required for the risk-significant SSCs in the SPRA model unless conservative or generic fragilities can be justified as being appropriate for the plant. The term "conservative" fragility refers to assumptions made in the fragility analysis that are purposely conservatively biased. For example, in a pump-fragility calculation, the analyst may determine nozzle loads on the pump without crediting all of the supports on the attached piping, which, if credited, would increase the pump capacity. Justification for the conservatively biased pump fragility can be provided by reviewing in detail the dominant SSC contribution in the overall risk profile. SSCs that have a small impact on the risk profile may not require realistic fragilities. These small-impact SSCs may be justified as appropriate for the plant through importance measures such as a low Fussell-Vesely value or by showing that further refinement in the fragility analysis would not appreciably change the SSC contribution. More detailed and realistic fragilities are required for SSCs that have a large impact on the overall risk profile if generic or conservative fragilities cannot be justified as appropriate. Justification for these large impact SSCs may include a sensitivity study that shows the result of an estimated higher capacity realistic fragility significantly changes neither the risk metrics nor the risk insights (e.g., does not create a masking concern). The combined effect of multiple generic or conservative fragilities should be considered in these sensitivity studies due to SSC dependency in the PRA model. The intent is to provide justification that no generic or conservative fragility is preventing an SSC from being identified as risk significant (e.g., masking the contribution of other SSCs) in the SPRA model. It is understood that these sensitivity studies may result in reordering of the top contributors or a single top-contributing SSC could drop in importance with the remainder not substantially changed, which would be acceptable. The masking concern would be a notable increase in risk significance (e.g., when a small contributor SSC instantly becomes a large contributor) during a sensitivity study on a large contributor SSC or group of SSCs. Some examples of generic fragilities that are often large contributors to an SPRA are LOOP and very small LOCA (VSLOCA). The use of generic fragilities may be appropriate for the plant, given justification. Some generic fragilities like the VSLOCA may provide a significant reduction in SCDF and/or SLERF when the median capacity is increased; however, a conservative value may still be acceptable if it is demonstrated that there is no masking effect. The term "failure mode" in SR SFR-E2 follows the same definition as in SR SFR-E1, that is, the seismically induced failure mechanism of interest in fragility calculations such as anchorage pullout, relay chatter, among many others.
SFR-E3	Functional failure of relays and other electromechanical contact devices is likely to occur under earthquake ground motions. Some of these functional failure modes may not affect the credited SPRA system functions (i.e., acceptable chatter), whereas others may lead to undesired system performance during an earthquake. For fragility analysis, the key analysis criterion is typically an assessment of a broadband capacity-to-demand comparison at the mounting point of the component over the frequency range of interest. Narrow banded demand and capacity peaks are typically clipped to determine the effective broadband capacity-to-demand evaluation. Relay and contactor seismic capacities are typically derived from shake-table testing. For CC-I, estimates of parameters such as the ISRS, electrical cabinet natural frequencies, effective cabinet amplification, and representative component capacities can be used. The use of generic or conservative estimates should be justified in accordance with SR SFR-E3. For CC-II, the fragility calculations are expected to be more realistic and make use of plant-specific data. Parameters used in the fragility calculations should be median centered without a conservative bias. The use of generic data should be justified in accordance with SR SFR-E3. For example, if more detailed fragility calculations for a relay or contactor would not result in a significant change in SCDF or SLERF, this evaluation can be used to demonstrate that the use of the generic or conservative fragility parameters are appropriate.
SFR-E4	No commentary provided.

Table 5-A.2.2-6 Commentary to Supporting Requirements for HLR-SFR-E (Cont'd)

Index No. SFR-E	Commentary
SFR-E5	The purpose of this SR is to capture potentially significant assumptions that may impact the quantification results (see SR SPR-E8). These assumptions are different from parametric uncertainties of variables affecting the fragility values of components that are already accounted for in the fragility analysis. In addition to identifying the potentially significant assumptions, an estimate of change in the fragility values of the affected components needs to be made so that the impact on the quantification results can be determined. Examples of potentially significant assumptions in fragility analysis include, but are not limited to *(a)* use of representative or conservative fragility values for risk-significant components (see SR SFR-E2 above) *(b)* use of generic seismic experience data in lieu of plant-specific seismic qualification test data for components *(c)* lumped mass spring models in lieu of 3D finite element models in the structural response analysis *(d)* neglecting the effects of structure-SSI *(e)* neglecting the effects of ground motion incoherence EPRI Technical Update 1026511 [5-A-24] expands on the above assumptions and provides more details for SPRA applications.

Table 5-A.2.2-7 Commentary to Supporting Requirements for HLR-SFR-F

Index No. SFR-F	Commentary
SFR-F1	The documentation of the fragility results needs to provide the required information such that the results obtained can be followed and replicated, if needed, in future PRA upgrades. A systematic process should be used in referencing different sources for information used in the analysis and calculations. The methodology used to perform the building seismic response and fragility analyses needs to be described in the documentation so that it could facilitate the peer-review process and be used for PRA applications. A thorough documentation of the judgments made by the engineers needs to be included to facilitate peer review.
SFR-F2	Sources of model uncertainty are documented, and their impact on the model needs to be evaluated. An example for the source of model uncertainty is an issue for which there is no consensus in approach (e.g., frequency range of interest, in-cabinet amplification factor used in relay fragilities, degree of cracking in buildings) and where the approach is known to have impact on the fragility analysis.

5-A.2.3 Commentary to Seismic Plant Response Analysis (SPR)

In general, the seismic plant-response model is developed from the internal-events PRA by first reviewing plant-safety systems from the perspective of seismic safety and subsequently modifying the event and fault trees according to the seismic-specific initiating events. Among the characteristics of an SPRA model are the inclusion of the entire range of postulated potential earthquake ground motion levels; the possibility that seismic events may damage passive SSCs typically not modeled in internal event PRAs; the possibility that seismic events may simultaneously damage multiple redundant SSCs, thus requiring a combination of plant-system responses; and consistent propagation of large uncertainties in the seismic hazard and fragility to produce the confidence ranges on SCDF and SLERF.

In recent years, significant advances in methodology for systems modeling and quantification in an SPRA have surfaced mainly due in part to the insights from the SPRAs in the United States in response to the NRC 50.54(f) letter [5-A-2]. These advances are in subjects such as seismic-induced fires and flooding, modeling of human response actions, and correlation between seismic failures. Significant progress has also been made toward a more integrated and collaborative effort between hazard, fragility, and systems analysts.

The requirements in the Seismic Plant Response Analysis were revised from the previous revision [5-A-4] of this Standard, with the intent to incorporate these advances in technology resulting from the performance of recent SPRAs in the United States. The commentary Notes are intended to clarify the intent of the requirements and to facilitate collaboration among other technical elements (i.e., Seismic Hazard Analysis and Seismic Fragility Analysis).

A general methodology for the modeling and quantification of an SPRA is documented in references such as EPRI-3002000709 [5-A-22], EPRI-1020756 [5-A-21], and EPRI-1025294 [5-A-25].

Table 5-A.2.3-1 Commentary to High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Seismic Plant Response Analysis (SPR)

Designator	Commentary
HLR-SPR-A	No commentary provided.
HLR-SPR-B	No commentary provided.
HLR-SPR-C	No commentary provided.
HLR-SPR-D	No commentary provided.
HLR-SPR-E	No commentary provided.
HLR-SPR-F	No commentary provided.

Table 5-A.2.3-2 Commentary to Supporting Requirements for HLR-SPR-A

Index No. SPR-A	Commentary
SPR-A1	The intent of this requirement is to ensure that the entire spectrum of seismically induced initiators is systematically evaluated, ranging from large catastrophic events resulting in major structural collapse to smaller magnitude events possibly resulting in a manual or automatic trip due to the seismic event being above operational limits. The requirement also focuses the attention of the analyst on combined events such as LOOP and/or a LOCA coincident with other initiators that are normally not considered in the initiating-event categorization used in the internal-events PRAs.
SPR-A2	Attention should be given to consequential events such as seismically induced fires, internal and external floods, and other similar events, as applicable. Existing guidance (see, e.g., [5-A-22]) provides a reasonably complete list of seismically induced external hazards to be addressed for the possibility of seismically induced events. As far as seismically induced internal floods and internal fires, the flood sources and fire-ignition sources identified as part of the internal-flood and internal-fire PRAs are, if available, an appropriate and consistent starting point. Note, finally, that this requirement works in conjunction with SR SHA-H1 and SR SHA-H2 in the identification of other nonvibratory hazards generated by the seismic event (e.g., soil liquefaction, fault displacement), with emphasis on the effect on the plant. In principle, any hazard that does not screen from further consideration in SR SHA-H1 and SR SHA-H2 needs to be picked up in the scope of the SPRA explicit modeling.
SPR-A3	No commentary provided.
SPR-A4	No commentary provided.

Table 5-A.2.3-3 Commentary to Supporting Requirements for HLR-SPR-B

Index No. SPR-B	Commentary
SPR-B1	No commentary provided.
SPR-B2	It has been shown that even minor unaddressed or insufficiently resolved significant deficiencies in the internal-events model can result in significantly amplified errors in the seismic model. Therefore, care should be taken to look for these cascading effects in the seismic model. The definition of significant deficiency needs to be considered in the context of the regulatory framework (i.e., outside of this Standard and on a country-by-country basis). In the United States, the PRA peer-review guidance indicates that a Finding-level observation impacts the technical adequacy of the PRA and is therefore a significant deficiency. Note that "significant" is in this context not to be strictly intended as risk significant.
SPR-B3	No commentary provided.
SPR-B4	No commentary provided.
SPR-B5	The fragility threshold value was previously referred to as "Screening-level fragility" in the technical community. The fragility threshold value represents a threshold in seismic capacity of an SSC that corresponds, when integrated with the site-specific hazard, to an event that is less than risk significant. As such, the SSC may be omitted from explicit modeling in the SPRA. The SR refers to SCR-2 in Table 1-1.8-1 because it is based on a relative screening criterion (i.e., relative to the total SCDF or SLERF). A fragility threshold value potentially addresses a large number of SSCs in the plant (tens or even hundreds of SSCs) and, therefore, the criterion associated with the cumulative screening in SCR-2 in Table 1-1.8-1 (i.e., the 5% criterion) is applicable. The 5% criterion is used, rather than the 1% criterion, because the latter is intended for screening discrete elements (e.g., one flood scenario, one fire scenario) rather than as a cumulative screening criterion. For SSCs whose failure would directly result in a core damage or large early release (e.g., major structures and NSSS items), the 1% criterion associated with individual elements would be applicable. The fragility threshold value may be different for CDF and LERF and should be defined independently from other screening considerations, if used, and from correlation groups and component grouping of fragilities. The EPRI SPID report [5-A-20]) established the 5% criteria as acceptable. While a fragility threshold value is likely selected early in the development of the SPRA to aid in the planning and execution of the fragility analysis effort, this SR is to be addressed in the context of the final SPRA.
SPR-B6	No commentary provided.
SPR-B7	No commentary provided.
SPR-B8	No commentary provided.
SPR-B9	No commentary provided.
SPR-B10	No commentary provided.
SPR-B11	No commentary provided.
SPR-B12	No commentary provided.
SPR-B13	The scope of the multi-unit assessment in this SR remains focused on the individual unit under consideration and does not expect a quantification of multi-unit CDF or LERF. Example of multi-unit impacts are the possibility of crediting shared equipment or the availability of crew from the additional units at sites.

Table 5-A.2.3-4 Commentary to Supporting Requirements for HLR-SPR-C

Index No. SPR-C	Commentary
SPR-C1	In practice, the SSCs included in the SEL are accompanied with essential details such as failure mode of interest, building location of component, component description, among others. NUREG-1407 [5-A-11] provides guidance on the details typically included in the SEL.
SPR-C2	No commentary provided.
SPR-C3	No commentary provided.
SPR-C4	No commentary provided.
SPR-C5	No commentary provided.
SPR-C6	Typical examples of failure modes of interest in an SPRA may include failure of a valve to open on demand, loss of function during earthquake, or rupture of pressure boundary. Note that these failure modes are defined by the systems analyst and may not be the same as the failure mechanisms defined by the fragility analyst. In practice, fragility analysts will identify the failure mechanism of a component based on vulnerabilities identified during the walkdowns (see SR SFR-D2) or the most likely lower-bound seismically induced failure mechanism typically based on experience, available test data, or analytical procedures. Thus, the importance for continuous interaction between systems and fragility analysts when defining the failure mechanism represented in a fragility curve and failure mode credited in the model. Another key interaction between the systems and fragility analysts involves eliminating from further consideration failure modes in the systems model that cannot realistically be affected by an earthquake and therefore need not be identified for fragility analysis in SR SPR-C6 as they are not "of interest for the Seismic Fragility Analysis." It is also worth noting that what SR SFR-E1 refers to as the "relevant" failure mechanism corresponds to the failure mode defined here in SR SPR-C6 by the systems analyst, say "failure to close" or "fail during earthquake." Once, this "relevant" failure mechanism has been clearly established, then the fragility analyst will proceed to assess which seismically induced failure could most likely lead to the failure mode defined here in SR SPR-C6. It may be possible that the systems analyst may be interested in the consequences rather than a seismically induced failure mode. An example for this case could be the failure definition of a motor control center (MCC). In one case, failure of the MCC may lead to adverse changes of state in the plant, and failure would be defined as loss of function during the seismic event. In another case, failure of the MCC during a seismic event may be acceptable, but after the event, the MCC should function. The fragility analyst will derive two distinctly different capacities (i.e., "function during" or "function after"). Another example for distinguishing consequences from failure modes is in the case of failure of heat exchangers. The fragility curve for a heat exchanger may be derived for failure of anchors. However, the consequences modeled in the SPRA model may be related to flooding of the area. Such a scenario indicates that there is still significant margin between the failure mechanism defined by the fragility analyst and the failure mode credited in the SPRA model. This scenario is an example of a source of considerable conservatism as the median capacity based on failure of the anchors will grossly underestimate the seismic capacity corresponding to the failure mechanism leading to flooding of the area. In most cases, precluding a more detailed analysis, the progressive failure mechanism, rather than pullout of an anchor, should be used to judge the overall contribution of such component to plant risk.

Table 5-A.2.3-5 Commentary to Supporting Requirements for HLR-SPR-D

Index No. SPR-D	Commentary
SPR-D1	No commentary provided.
SPR-D2	No commentary provided.
SPR-D3	No commentary provided.
SPR-D4	No commentary provided.
SPR-D5	No commentary provided.

Table 5-A.2.3-6 Commentary to Supporting Requirements for HLR-SPR-E

Index No. SPR-E	Commentary
SPR-E1	No commentary provided.
SPR-E2	No commentary provided.
SPR-E3	Convergence needs to be confirmed during the quantification of the SPRA. In an SPRA, convergence is driven by factors beyond the simple truncation used in quantification. Especially for quantification codes where the user can select and manipulate the number and size of the hazard and fragility intervals used in the quantification, those parameters need to be investigated for their impact on the quantification. Large hazard intervals can overpredict the risk metrics and skew the importance measures. The selection of the representative acceleration values for each hazard can also have an impact on the result stability.
SPR-E4	Caution should be taken when satisfying SR QU-B3 in Part 2. The 5% truncation rule noted in that SR is viewed to only be an *example* and is not intended to be a *requirement*.
SPR-E5	No commentary provided.
SPR-E6	This SR addresses parametric uncertainty explicitly, as SR SPR-E4 omits the uncertainty portion of quantification via the back reference. It is assumed in this SR that a LERF model for internal events is used as a basis for the SPRA. The analysis of the LERF end point proceeds in the same way as the analysis of the CDF end point, with one major exception, as follows: There are some accident sequences leading to core damage but not to large early releases in the internal-events PRA model that need to be designated as potential LERF sequences when caused by a seismic event. One set of sequences is those where the effects of the earthquake might compromise containment integrity and thereby possibly contribute to LERF. The other set is sequences in which off-site protective action (specifically, the evacuation of nearby populations) is impeded due to the earthquake. The same sequence that might not be a LERF sequence due to any internal hazard may perhaps affect nearby populations that cannot evacuate as effectively (see definition of large early release in Section 1-2.2). The SRs referenced in Table 2-2.7-6 (HLR-QU-E) are written in CDF language. The applicable requirements of Table 2-2.7-6 should be interpreted based on LERF, including characterizing the sources of model uncertainty and related assumptions associated with the applicable contributors from Table 2-2.8-9.
SPR-E7	It is assumed in this SR that a LERF model for internal events is used as a basis for the SPRA. Caution should be taken when performing and reviewing this SR. The analysis of the LERF end point proceeds in the same way as the analysis of the CDF end point with one major exception: There are some accident sequences leading to core damage but not to large early releases in the internal-events PRA model that need to be designated as potential LERF sequences when caused by an external hazard. One set of sequences is that in which the effects of the external hazard might compromise containment integrity and thereby possibly contribute to LERF. The other set is sequences in which off-site protective action (specifically the evacuation of nearby populations) is impeded due to the external hazard. The same sequence that might not be an LERF sequence due to any internal hazard may perhaps affect nearby populations that cannot evacuate as effectively (see definition of "large early release" in Section 1-2.2).
SPR-E8	No commentary provided.

Table 5-A.2.3-7 Commentary to Supporting Requirements for HLR-SPR-F

Index No. SPR-F	Commentary
SPR-F1	No commentary provided.
SPR-F2	No commentary provided.
SPR-F3	Refer to Part 1 for definition of source of model uncertainty.
SPR-F4	No commentary provided.

5-A.3 REFERENCES

The following is a list of publications referenced in this Appendix.

[5-A-1] Information Notice 2010-18, "Generic Issue 199, 'Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants,'" under ML101970221, September 2, 2010; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[5-A-2] E. Leeds and M. Johnson, Letter to All Power Reactor Licensees et al., "Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3 and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident," under ML12053A340, March 12, 2012; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[5-A-3] EPRI Report 3002000717, "EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project," June 2013; Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[5-A-4] ASME/ANS RA-Sb-2013 (R2019), "Addenda to ASME/ANS RA-S-2008 Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications," American Society of Mechanical Engineers (ASME) and American Nuclear Society (ANS), 2013; ASME, Two Park Avenue, New York, NY 10016-5990

[5-A-5] JCNRM RA-S Case 1-1, Revisions to Case 1, "Alternative Requirements for a Seismic PRA," The American Society of Mechanical Engineers (ASME) and the American Nuclear Society (ANS), Joint Committee Nuclear Risk Management (JCNRM), June 2019, https://cstools.asme.org/csconnect/CommitteePages.cfm?Committee=100186782&Action=52983

[5-A-6] NUREG-2213, "Updated Implementation Guidelines for SSHAC Hazard Studies," October 2018; U.S. Nuclear Regulatory Commissions (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[5-A-7] NUREG-2117, Rev. 1, "Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies," April 2012; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[5-A-8] NUREG/CR-6372 and UCRL-ID-122160, R. J. Budnitz, D. M. Boore, G. Apostolakis, L. S. Cluff, K. J. Coppersmith, C. A. Cornell, and P. A. Morris, "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts," Lawrence Livermore National Laboratory, April 1997; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[5-A-9] INL/EXT-15-36510, Rev. 1, "Proposed Risk-Informed Seismic Hazard Periodic Reevaluation Methodology for Complying with DOE Order 420.1C," A. M. Kammerer, R. J. Budnitz, N. C. Chokshi, and K. Coppersmith, November 2015; Idaho National Laboratory (INL), 1955 N. Fremont Avenue, Idaho Falls, ID, 83415

[5-A-10] NUREG-2115, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities," Electric Power Research Institute (EPRI), U.S. Department of Energy (DOE), and U.S. Nuclear Regulatory Commission (NRC), 2012; NRC, One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[5-A-11] NUREG-1407, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities," June 1991; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[5-A-12] NUREG/CR-6728, "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-consistent Ground Motion Spectra Guidelines," R. K. McGuire, W. J. Silva, and C. J. Costantino, October 2001; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[5-A-13] Regulatory Guide 1.132, Rev. 2, "Site Investigations for Foundations of Nuclear Power Plants," October 2003; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[5-A-14] Regulatory Guide 1.138, Rev. 3, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants," December 2014; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[5-A-15] Regulatory Guide 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," March 2007; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[5-A-16] EPRI Report 3002012994, "Seismic Fragility and Seismic Margin Guidance for Seismic Probabilistic Risk Assessments," 2018; Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[5-A-17] NUREG/CR-7237, "Correlation of Seismic Performance in Similar SSCs (Structures, Systems, and Components)," R. J. Budnitz, G. S. Hardy, D. L. Moore, and M. K. Ravindra, Lawrence Berkeley National Laboratory, December 2017; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[5-A-18] ASCE/SEI 4-16, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary," American Society of Civil Engineers (ASCE)/Structural

Engineering Institute (SEI), April 2017; ASCE, 1801 Alexander Bell Drive, Reston, VA, 20191-4382

[5-A-19] EPRI NP 6041-SL, Rev. 1, "A Methodology for Assessment of Nuclear Power Plant Seismic Margin," NTS Engineering, RPK Structural Mechanics Consulting, Pickard, Lowe and Garrick, Woodward Clyde and Consultants, and Duke Power Company, 1991;Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[5-A-20] EPRI Report 1025287, Rev. 0, "Seismic Evaluation Guidance—Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic," 2013; Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[5-A-21] EPRI Report 1020756, "Surry Seismic Probabilistic Risk Assessment Pilot Plant Review," 2010;Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[5-A-22] EPRI Report 3002000709, "Seismic Probabilistic Risk Assessment Implementation Guide," 2013; Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[5-A-23] "Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment," Rev. 3A, 2001; Seismic Qualification Utility Group (SQUG), https://www.nrc.gov/docs/ML0405/ML040560263.pdf (current as of December 31, 2021)

[5-A-24] EPRI Technical Update 1026511, "Practical Guidance on the Use of Probabilistic Risk Assessment in Risk-Informed Applications with a Focus on the Treatment of Uncertainty," 2012; Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[5-A-25] EPRI Report 1025294, "A Preliminary Approach to Human Reliability Analysis for External Events with a Focus on Seismic," 2012; Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[5-A-26] JCNRM Inquiry Record 20-2435, The American Society of Mechanical Engineers (ASME) and the American Nuclear Society (ANS), Joint Committee on Nuclear Risk Management (JCNRM) Inquiries and Interpretations, ASME, website link: https://cstools.asme.org/csconnect/CommitteePages.cfm?Committee=100186782&Action=40886

PART 6 REQUIREMENTS FOR SCREENING AND CONSERVATIVE ANALYSIS OF HAZARDS FOR AT-POWER PRA

Section 6-1 Overview of Screening and Conservative Analysis Requirements

6-1.1 SCOPE

This Part states the technical requirements for performing screening and conservative analyses for internal and external hazards for a plant while at-power. Internal events (Part 2), internal floods (Part 3), internal fires (Part 4), natural tectonic earthquakes (Part 5), high winds (Part 7), and external floods (Part 8) are not subject to screening under this Part.

6-1.2 COORDINATION WITH OTHER PARTS OF THIS STANDARD

This Part states the requirements for screening out hazards from further consideration in the PRA. Part 6 Supporting Requirements (SRs) refer to Part 1 for the specific screening criteria.

For those hazards that cannot be screened out pursuant to Part 6, the requirements in Part 9 of this Standard are used (in conjunction with requirements in other Parts, e.g., Part 1, Part 2, Part 3, and Part 4, as applicable) to perform more detailed analyses.

(The text presented in **blue font** in this Standard comprise hyperlinks to enable efficient access to referenced sections and elements, requirements, notes, references, etc.)

Section 6-2
Screening and Conservative Analysis Technical Requirements

The requirements in this Part are concerned with screening out hazards. The term "screening out" is used here for the process whereby a hazard is excluded from further evaluation in a PRA. This screening process is not intended to restrict the analyst from screening out specific hazard events resulting from the hazard if the screening analysis can be done with a documented basis that meets the requirements of this standard and if the screened-out hazard event and the remaining hazard events are mutually exclusive. For example, it is acceptable to subdivide transportation accidents into individual hazards and thereby screen out all except aircraft impact, then subdivide this hazard into specific aircraft impact events to screen out large jets and crop dusters, and then to subject only military jets to detailed PRA analysis by using the requirements in Part 9. The intent is not to unreasonably subdivide a hazard into numerous discrete events as a means to screen out the entire hazard.

Note that the above discussion does not mention screening out an entire hazard group. Although hazard groups can be characterized by common approach, methods, and data, this commonality is not always the case, and each hazard must be screened individually.

It should be understood that the requirements of this Part are applicable when it is desired to determine if a specific hazard (or mechanism) may be eliminated from detailed PRA by using a screening process. A list of hazards that have been identified in past industry studies is provided as information in Nonmandatory Appendix (NMA) 6-B. A screening assessment using this list is one acceptable approach to meeting SR EXT-A1.

At any time during the screening process, a decision can be made to bypass that process and go directly to the detailed analysis requirements of Part 9. Requirements for detailed analyses of a hazard that cannot be screened out by using either the qualitative criteria in HLR-EXT-B or the quantitative criteria in HLR-EXT-C are stated in Part 9.

The requirements of this Part are organized into one technical element titled Screening and Conservative Analysis (EXT).

6-2.1 SCREENING AND CONSERVATIVE ANALYSIS (EXT)

6-2.1.1 Objective

The objective of the Screening and Conservative Analysis is to provide requirements for performing screening and conservative analyses to exclude a hazard or hazard group from further evaluation by

(a) identifying all potential hazards that may affect the nuclear power plant

(b) specifying a set of qualitative screening criteria

(c) using a demonstrably conservative analysis when quantitively screening out a hazard

(d) conducting a walkdown to establish or confirm as-built, as-operated conditions

(e) documenting the hazard screening analysis to provide traceability of the work

The five High Level Requirements (HLRs) of Part 6 are stated in Table 6-2.1-1. The SRs are stated in Table 6-2.1-2, Table 6-2.1-3, Table 6-2.1-4, Table 6-2.1-5, and 6-2.1-6. Note that Part 6 does not include separate requirements for Capability Category I (CC-I) and Capability Category II (CC-II).

Table 6-2.1-1 High Level Requirements for Screening and Conservative Analysis of Hazards (EXT)

Designator	Requirement
HLR-EXT-A	Potential hazards that may affect the site shall be identified.
HLR-EXT-B	Qualitative screening, if performed, shall use a defined set of screening criteria.
HLR-EXT-C	A demonstrably conservative analysis, if used for screening, shall be performed using defined quantitative screening criteria.
HLR-EXT-D	The hazard screening evaluation shall incorporate the data and findings of walkdown(s) of the plant (and its surroundings, as applicable to the hazard) to establish or confirm as-built, as-operated conditions.
HLR-EXT-E	Documentation of the screening and demonstrably conservative analysis shall provide traceability of the work.

Table 6-2.1-2 Supporting Requirements for HLR-EXT-A

Potential hazards that may affect the site shall be identified (HLR-EXT-A).

Index No. EXT-A	Capability Category I	Capability Category II
EXT-A1	IDENTIFY hazards and hazard groups that include those enumerated in industry guidelines and examined in past studies.	
EXT-A2	IDENTIFY site-specific and plant-unique hazards and hazard groups not already identified in SR EXT-A1.	
EXT-A3	IDENTIFY secondary hazards associated with hazards and hazard groups from SR EXT-A1 and SR EXT-A2.	

Table 6-2.1-3 Supporting Requirements for HLR-EXT-B

Qualitative screening, if performed, shall use a defined set of screening criteria (HLR-EXT-B).

Index No. EXT-B	Capability Category I	Capability Category II
EXT-B1	REVIEW information about *(a)* the plant's design and licensing basis relevant to each hazard *(b)* region-, industry-, government-, and plant-funded evaluations for each hazard, if available	
EXT-B2	REVIEW significant changes or updates since the operating license was issued. In particular, as germane to the given hazard, review all of the following: *(a)* military and industrial facilities in proximity of the site *(b)* on-site storage or other activities involving hazardous materials *(c)* nearby transportation *(d)* nearby pipelines *(e)* air routes *(f)* other on-site or off-site changes that could affect the original design conditions	
EXT-B3	INCLUDE consideration of secondary hazard(s) in the qualitative screening process for hazards or hazard groups.	
EXT-B4	USE SCR-3 from Table 1-1.8-1 when screening out a hazard or hazard group by showing at least one of the following: *(a)* The hazard or hazard group cannot physically impact the plant or plant operations (e.g., it cannot occur close enough to the plant to affect it). *(b)* The hazard or hazard group does not result in a plant trip (manual or automatic) or require a plant shutdown. *(c)* The hazard or hazard group is included in the definition of another hazard that is included in the PRA. *(d)* The hazard or hazard group could not result in worse effects to the plant or plant operations than another hazard that has a significantly higher frequency. *(e)* The hazard or hazard group is slow in developing, and it is shown that there is a demonstrably conservative estimate of time margin available to eliminate the source of the threat or to provide an adequate response.	

Table 6-2.1-4 Supporting Requirements for HLR-EXT-C

A demonstrably conservative analysis, if used for screening, shall be performed using defined quantitative screening criteria (HLR-EXT-C).

Index No. EXT-C	Capability Category I	Capability Category II
EXT-C1	CALCULATE either the mean or demonstrably conservative frequency of occurrence or exceedance (as applicable) and associated parameters (e.g., loading magnitudes) of the hazards not qualitatively screened out in HLR-EXT-B.	
EXT-C2	USE applicable databases and information to satisfy the SRs of this HLR.	
EXT-C3	IDENTIFY those structures, systems, and components (SSCs) and associated failure modes that are required to maintain the plant in operation or to respond to an initiating event to prevent core damage but that are vulnerable to the hazard.	
EXT-C4	USE the internal-events PRA initiating events and accident sequences for both core damage frequency (CDF) and large early release frequency (LERF) as the basis for development of the hazard screening plant-response model.	
EXT-C5	ENSURE that the peer review findings for the internal-events PRA and other PRAs that are relevant to the hazard screening quantitative analyses are resolved and incorporated into the hazard screening plant-response model.	
EXT-C6	CALCULATE demonstrably conservative conditional core damage probability (CCDP) and/or conditional large early release probability (CLERP) using the internal-events plant-response model or by assuming a CCDP and/or CLERP of unity (1.0). If additional plant-response modeling is performed, SATISFY the requirements in HLR-SY-A and HLR-SY-B in Part 2 for Systems Analysis, except where the requirements are not applicable.	
EXT-C7	CALCULATE demonstrably conservative CDF (and LERF) on a reactor-year basis for the hazard using one of the following: *(a)* for discrete hazard, use the product of the hazard frequency and CCDP (and CLERP), as calculated in SR EXT-C6 *(b)* for hazard characterized by hazard curve, divide the hazard curve into hazard intervals and sum for all intervals the product of the hazard interval frequency and associated interval CCDP (and interval CLERP), as calculated in SR EXT-C6 *(c)* include the hazard-induced initiating events and the systems or functions assumed rendered unavailable by the hazard into the internal-events PRA model *(d)* use a hazard specific model, as appropriate, with demonstrably conservative assessments of the impact of the hazard (fragility evaluation)	
EXT-C8	ADDRESS secondary hazard(s) in the hazard quantitative screening process.	
EXT-C9	When human actions are credited in the screening evaluation, ENSURE that hazard-induced impacts on human error probabilities are included as applicable.	
EXT-C10	For quantitatively screening out a hazard within the scope of Part 6 based on the results of SR EXT-C7, USE the screening criteria in either SCR-1 or SCR-2 in Table 1-1.8-1.	
EXT-C11	IDENTIFY the sources of uncertainty, the related assumptions, and reasonable alternatives, if available, related to identification, quantitative screening, and qualitative screening of hazards.	

Table 6-2.1-5 Supporting Requirements for HLR-EXT-D

The hazard screening evaluation shall incorporate the data and findings of walkdown(s) of the plant (and its surroundings, as applicable to the hazard) to establish or confirm as-built, as-operated conditions (HLR-EXT-D).

Index No. EXT-D	Capability Category I	Capability Category II
EXT-D1	INCLUDE data and findings of walkdown(s) of the plant (and its surroundings, as applicable to the hazard) in the screening out of a given hazard to establish or confirm as-built, as-operated conditions.	

Table 6-2.1-6 Supporting Requirements for HLR-EXT-E

Documentation of the screening and demonstrably conservative analysis shall provide traceability of the work (HLR-EXT-E).

Index No. EXT-E	Capability Category I	Capability Category II
EXT-E1	DOCUMENT the process used in the screening out of hazards by specifying what is used as input, the applied methods, and the results. The documentation includes, as a minimum, *(a)* a list of hazards addressed in the analysis and which hazards were screened out from further detailed analyses *(b)* the approach used for the screening (qualitative screening or demonstrably conservative analysis) and the screening criteria used for each hazard or hazard group that is screened out *(c)* engineering or other analysis performed to support the screening out of a hazard or hazard group or in the demonstrably conservative assessment of a hazard or hazard group *(d)* CDF and LERF results from quantitative screening calculations	
EXT-E2	DOCUMENT the sources of uncertainty, the related assumptions, and reasonable alternatives associated with the screening out of hazards or hazard groups as identified in SR EXT-C11.	

NONMANDATORY APPENDIX 6-A SCREENING COMMENTARY

6-A.1 INTRODUCTION

This Nonmandatory Appendix provides notes and general explanatory material tied to specific SRs as stated in Part 6 of this Standard. The material contained in this Appendix is nonmandatory and, as such, does not establish new requirements; rather, the material is intended to clarify the intent of an SR, explain jargon that might be used in an SR, and/or provide examples of analysis approaches that would meet the intent of the SR.

6-A.2 COMMENTARY TO SCREENING AND CONSERVATIVE ANALYSIS TECHNICAL REQUIREMENTS

6-A.2.1 COMMENTARY TO SCREENING AND CONSERVATIVE ANALYSIS (EXT)

Table 6-A.2.1-1 Commentary to High Level Requirements for Screening and Conservative Analysis of Hazards (EXT)

Designator	Commentary
HLR-EXT-A	No commentary provided.
HLR-EXT-B	No commentary provided.
HLR-EXT-C	No commentary provided.
HLR-EXT-D	No commentary provided.
HLR-EXT-E	No commentary provided.

Table 6-A.2.1-2 Commentary to Supporting Requirements for HLR-EXT-A

Index No. EXT-A	Commentary
EXT-A1	Part 5 addresses natural tectonic earthquakes. This commentary focuses on the hazard of human-induced earthquakes (e.g., due to extraction of fossil fuels, mining activities), which are screened as appropriate by using Part 6. The following example criteria for screening out are suggested for consideration: *(a)* The closest distance between the site and the location of recorded earthquakes that are considered as seismicity that is induced or triggered by human activities is greater than 200 miles from the site. *(b)* The magnitude of induced or triggered earthquakes is below that used to derive the earthquake recurrence models, implying that the suite of recurrence models used for the probabilistic seismic hazard analysis remains appropriate. *(c)* The rate of induced or triggered earthquakes would not increase the mean recurrence rate for any of the seismic sources that are within 200 miles of the site by more than 10%. *(d)* Median ground motions estimated by using the closest distance and the maximum expected magnitude for induced or triggered events are less than ground motions at a mean annual frequency of exceedance of 1.0E-3. Ground motions should be evaluated for both peak ground acceleration and 10 Hz spectral acceleration.
EXT-A2	The purpose of this requirement is to ensure that an unusual type of hazard is not inadvertently omitted simply because it does not fit into any of the listed hazards commonly considered and listed in the standard references in SR EXT-A1.
EXT-A3	No commentary provided.

Table 6-A.2.1-3 Commentary to Supporting Requirements for HLR-EXT-B

Index No. EXT-B	Commentary
EXT-B1	In the siting and plant design stage, most site-specific natural and manmade hazards will have been addressed and included in the design basis unless they were screened out by using the licensing criteria described in the NRC Standard Review Plan and Regulatory Guides. Such documented information can be useful input and reference information in the Part 6 screening process.
EXT-B2	Items *(a)* through *(e)* of the list in this SR are specifically identified because they represent the most common areas where a significant change might have occurred since the issuance of the operating license.
EXT-B3	No commentary provided.
EXT-B4	Qualitative hazard screening is a basic aspect of PRA. It is a practical analysis step to properly limit PRA modeling while retaining a clear focus on important contributors to risk. The underlying intent of the qualitative screening criteria is to ensure that items that are screened out from further analysis do not impact the integrity and insights provided by a PRA model. The qualitative screening criteria of this SR have been used since the early 1980s in many international PRAs and PRA guidelines. Various industry and regulatory guidelines exist regarding scoping or qualitative screening for base PRA modeling as well as for PRA applications. For example, NUREG-1855 [6-A-1] provides NRC interpretations of hazard qualitative screening criteria. Some industry guidelines (e.g., IAEA SSG-3, [6-A-2]) also include qualitative consideration of uncertainties in hazard initiating event frequencies (the spread of the uncertainty and the detail of the analysis estimate) in the determination of qualitative screening. If the confidence in the calculations is high (narrow uncertainty bands), the qualitative screening conclusion may be different from when the confidence is low (wide uncertainty bands) when considering the ratio of the mean values. Also, if one calculation uses more realistic assumptions versus demonstrably conservative ones (e.g., for convenience, to save effort), the conclusion regarding what is significant may be different. NRC has performed research into the treatment of uncertainty and its use in decision-making. As an example, NUREG-1855 [6-A-1] provides guidance on one possible way to interpret the meaning of "significantly higher" in the context of hazard frequencies [an example would relate to criterion *(d)* of this SR], as described in the converse phrase "significantly lower." NUREG-1855 [6-A-1] states that "significantly lower" means that the contributor or hazard under consideration has a mean frequency of occurrence that is at least two orders of magnitude less than (i.e., 1%) the frequency of occurrence of the compared contributor or hazard. In the implementation to SR EXT-B4 screening criterion *(d)*, it is appropriate and useful to the qualitative screening process to consider differences in the level of rigor between different hazard analyses. This SR does not cite specific quantitative criteria that must be used in the implementation of the SR EXT-B4 qualitative screening criteria.

Table 6-A.2.1-4 Commentary to Supporting Requirements for HLR-EXT-C

Index No. EXT-C	Commentary
EXT-C1	The initiator frequency estimation recognizes that, for convenience or analyst preference, a mean occurrence frequency may be calculated or obtained from an industry study, as opposed to estimating a demonstrably conservative initiator frequency. Subsequent HLR-EXT-C SRs impose the demonstrably conservative aspect; as such, selection of a mean frequency will still result in a demonstrably conservative screening analysis.
EXT-C2	No commentary provided.
EXT-C3	No commentary provided.

Table 6-A.2.1-4 Commentary to Supporting Requirements for HLR-EXT-C (Cont'd)

Index No. EXT-C	Commentary
EXT-C4	As part of the development of the hazard screening plant-response model, new initiating events, unmodeled plant conditions, or accident sequences may need to be added to the internal-events PRA model to represent the impacts of the hazard for the range of magnitudes under consideration. For example, multiple failures coupled with previously unmodeled plant conditions or plant response may result in unexpected outcomes for hazard events of different magnitudes. These examples are typical PRA modeling techniques that may be called upon when performing this aspect of quantitative screening for a given hazard.
EXT-C5	No commentary provided.
EXT-C6	Because HLR-EXT-C is for a conservative screening process, this SR *does not* specify multiple capability categories reflecting the multiple capability categories used in some of the referenced Systems Analysis SRs in Part 2. Systems Analysis models are typically already CC-II, and any new system fault-tree work for HLR-EXT-C conservative screening can be CC-I at a minimum.
EXT-C7	Similar to an internal-events PRA, the quantitative screening CDF and LERF results will typically include the plant availability factor as part of the quantification. However, given that this specific analysis is for quantitative screening purposes, it is not critical here if the plant availability factor is not explicitly included in the screening quantification, as that would result in more conservatism in the screening results. Because the purpose of Part 6 is screening hazards, all the quantification requirements in the Quantification and LERF Analysis technical elements of Part 2 (e.g., parametric uncertainty analysis, risk importance presentation) are not necessary in the performance of quantitative screening. It is important to recognize that a demonstrably conservative estimate of a mean value is not a point estimate. When uncertainties are large, the mean frequency can fall above the 95th percentile of the distribution. Therefore, it is incumbent on the analyst to document the evidence that justifies estimates of uncertainties, approximations, or simplifications leading to the estimate of the mean event frequency or CDF. Concerning LERF, the implicit assumption is that if a hazard is screened out by using one or another of the screening criteria herein, then neither the CDF nor the LERF arising due to that event is of concern. This assumption is made even though only limited consideration is given in the screening to LERF issues (e.g., during the walkdown, a review of spatial interactions is required). Calculation of the CDF may be done using different demonstrably conservative assumptions, as explained by the following example. Typically, nuclear power plants are sited such that the accidental impact of plant structures by aircraft is highly unlikely. As part of the hazard PRA, the risk from aircraft accidents may be assessed at different levels. The mean annual frequency of aircraft impact during takeoff, landing, or in flight may be determined. If this hazard frequency is very low, then the aircraft impact as a hazard may be eliminated from further study. This approach assumes that the aircraft impact results in damage of the structure, leading to core damage or large early release (this assumption is likely to be highly conservative). If the frequency of aircraft impacting the plant structures is estimated to be higher, the fragility of the structures may be evaluated to make a refined estimate of the frequency of core damage. Further refinements could include *(a)* eliminating certain structural failures as not resulting in core damage (e.g., damage of diesel generator building may not result in core damage if off-site electrical power is available) *(b)* performing a plant-systems and accident-sequence analysis to calculate the CDF This example shows that for some hazards, it may be sufficient to perform only the hazard analysis; for others, the hazard analysis and a simple fragility evaluation may be needed; in rare cases, a plant-systems and accident-sequence analysis may be necessary. For other examples of demonstrably conservative analysis, see references [6-A-3], [6-A-4], [6-A-5], and [6-A-6].
EXT-C8	No commentary provided.
EXT-C9	No commentary provided.
EXT-C10	No commentary provided.
EXT-C11	No commentary provided.

Table 6-A.2.1-5 Commentary to Supporting Requirements for HLR-EXT-D

Index No. EXT-D	Commentary
EXT-D1	The general hazard screening walkdown should concentrate, although not exclusively, on outdoor facilities that could be affected by on-site hazards (e.g., on-site storage of hazardous materials) and off-site developments such as increased usage of new airports/airways, highways, and gas pipelines. The purpose of this SR is to direct the analyst to look beyond the plant-licensing documents.

Table 6-A.2.1-6 Commentary to Supporting Requirements for HLR-EXT-E

Index No. EXT-E	Commentary
EXT-E1	No commentary provided.
EXT-E2	No commentary provided.

6-A.3 REFERENCES

The following is a list of publications referenced in this Appendix.

[6-A-1] NUREG-1855, Rev. 1, "Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decisionmaking," 2017; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[6-A-2] IAEA Safety Standards Series No. SSG-3, "Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants," 2010; International Atomic Energy Agency (IAEA), Vienna International Centre, 1400 Vienna, Austria

[6-A-3] NUREG/CR-4550, Vol. 4, Rev. 1, Part 3, and SAND-86-2084, Vol.4, Rev.1, Part 3, "Analysis of Core Damage Frequency: Peach Bottom, Unit 2 External Events," J. A. Lambright et al., U.S. Nuclear Regulatory Commission (NRC) and Sandia National Laboratories (SNL), 1990; NRC, One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[6-A-4] NUREG/CR-4839 and SAND87-7156, "Methods for External Event Screening Quantification: Risk Methods Integration and Evaluation Program (RMIEP) Methods Development," M. K. Ravindra and H. Bannon, U.S. Nuclear Regulatory Commission (NRC) and Sandia National Laboratories (SNL), 1992; NRC, One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[6-A-5] NUREG/CR-4832, Vol. 7, and SAND92-0537, Vol. 7, "Analysis of the LaSalle Unit 2 Nuclear Power Plant: Risk Methods Integration and Evaluation Program (RMIEP): External Event Scoping Quantification," M. K. Ravindra and H. Bannon," U.S. Nuclear Regulatory Commission (NRC) and Sandia National Laboratories (SNL), 1992; NRC, One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[6-A-6] NUREG/CR-5042, and UCID-21223, "Evaluation of External Hazards to Nuclear Power Plants in the United States," C. Y. Kimura and R. J. Budnitz, U.S. Nuclear Regulatory Commission (NRC) and Lawrence Livermore National Laboratory (LLNL), 1987; NRC, One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

NONMANDATORY APPENDIX 6-B
LIST OF HAZARDS FOR CONSIDERATION

Table 6-B-1 provides a typical list of internal and external hazard groups and their associated hazards. This list of hazards is compiled based on review of industry studies such as NUREG/CR-2300 [6-A-1], NUREG-1407 [6-B-2], IAEA SSG-3 [6-B-3], NUREG/CR-5042 [6-B-4], EPRI 1022997 [6-B-5], EPRI 3002005287 [6-B-6], and ASAMPSA_E List of External Hazards [6-B-7]. Note that some studies identify hazards broadly (e.g., chemical release), whereas other studies identify hazards more specifically (e.g., ground contamination from chemicals, chemical release into water), and some studies provide miscellaneous hazards not listed in Table 6-B-1 (e.g., corrosion, solar storm, air pollution, and mist). Table 6-B-1 does not explicitly list internal events (Part 2), internal flooding (Part 3), and internal fires (Part 4).

Table 6-B-1 List of Hazards for Consideration

Hazard Group [Note (1)]	Hazard	Remarks [Notes (2), (3), (4)]
Animals	Animals	Land or flying animals can cause damage to plant equipment (e.g., loss of off-site power [LOOP]) or result in other hazards (e.g., transportation accidents). Impact on intake water from fish, mussels, and waterborne items are addressed by other hazards below.
Biological events	Biological events	This hazard includes events such as detritus and zebra mussels blocking intake structure screens.
External fire	Forest fire	Plant design and fire-protection provisions often are adequate to mitigate the effects; however, site-specific analyses may be necessary to evaluate fire propagation (e.g., airborne firebrand transport).
	Grass fire	Fire often cannot propagate to or on the site because the site is cleared; plant design and fire-protection provisions are typically adequate to mitigate the effects; however, this can be confirmed via walkdowns.
	Nonsafety building fire	Fire often cannot propagate to safety areas of a plant; separation, plant design, and fire-protection provisions are often adequate to mitigate the effects; however, this adequacy can be confirmed via walkdowns.
Extraterrestrial events	Meteorite or satellite impact	This is a low-likelihood hazard; however, effects are not limited to direct impact but also include other related potential effects of indirect impacts or airburst events (e.g., total thermal exposure, overpressure, seismic event, ejecta).
Extreme temperature	Frost	Frost is subsumed in snow and ice hazards.
	High summer temperature	Analysis can often be excluded where the ultimate heat sink is designed for at least 30 days of operation, including evaporation, drift, seepage, and other water-loss mechanisms. Evaluation is needed of possible loss of air cooling due to high temperatures.
	Ice cover	Ice blockage of river is included in flood; loss of cooling-water flow is considered in plant design.
	Low winter temperature	Thermal stresses and embrittlement are usually insignificant or covered by design codes and standards for plant design; generally, there is adequate warning of icing on the ultimate heat sink so that remedial action can be taken. However, the reliability of operator actions and equipment used to protect vulnerable SSCs (e.g., heat tracing on water-carrying pipes) may need to be evaluated
Ground shifts	Avalanche (rock or debris)	This hazard can be excluded for most nuclear plant sites; confirm through siting review or walkdown.
	Coastal erosion	This hazard is included in the effects of external flooding (Part 8).
	Landslide	This hazard can be excluded through siting review; confirm through walkdown.
	Sinkholes	Site-suitability evaluation and site development for the plant are designed to preclude the effects of this hazard.
	Soil shrink–swell	Site-suitability evaluation and site development for the plant are designed to preclude the effects of this hazard.

Table 6-B-1 List of Hazards for Consideration (Cont'd)

Hazard Group [Note (1)]	Hazard	Remarks [Notes (2), (3), (4)]
Heat-sink effects	Drought	Drought can often be excluded where there are multiple sources of ultimate heat sink or where the ultimate heat sink is not affected by drought (e.g., cooling tower with adequately sized basin).
	Frazil ice	Frazil ice is a slush of ice crystals that can rapidly form in turbulent water. It is site specific.
	Low lake or river water level	This hazard may result from failure of a downstream dam. It can often be excluded where the ultimate heat sink is designed for at least 30 days of operation, including evaporation, drift, seepage, and other water-loss mechanisms if there is no downstream dam failure.
	River diversion	This hazard is considered in the evaluation of the ultimate heat sink; should diversion become a hazard, adequate storage is usually provided.
Heavy-load drop	Heavy-load drop	This hazard is site specific and requires detailed study.
High winds	Straight Winds	This hazard is site specific and requires detailed study. See Part 7 for screening and detailed PRA.
	Tornadoes	This hazard is site specific and requires detailed study. See Part 7 for screening and detailed PRA.
	Tropical Cyclones (i.e., Hurricane, Typhoon)	This hazard involves both wind forces and external flooding. Wind forces are covered under extreme winds and tornadoes. See Part 7 and Part 8 for screening and detailed PRA.
	Sandstorm	Note that potential blockage of air intakes with particulate matter is generally considered in plant design; however, other adverse effects may need to be considered (e.g., particulate intrusion into electrical equipment).
	Hail	Other missiles govern.
Industrial accidents	Industrial or military facility accident	This hazard includes externally generated missiles. It is site specific and may be screened based on proximity to site.
	Pipeline accident	This hazard may include both chemical release and/or explosion. It may be screened based on proximity to the site and content of the pipeline. It is site specific.
	Release of chemicals from on-site storage	This hazard is plant specific and requires detailed study.
	On-site excavation work	This hazard is a temporary condition and is site specific.
	Toxic gas	This hazard is site specific and requires detailed study.
Lightning	Lightning	Lightning is considered in plant design and may not trip the plant; LOOP often includes this contributor.
Seismic	Natural tectonic earthquakes	This hazard is site specific and requires detailed study (see Part 5).
	Human-induced earthquakes	This hazard includes such causes as extraction of fossil fuels and mining activities.
External flooding [Note (5)]	High tide	This hazard is included under external flooding.
	Precipitation, intense	This hazard is included under external and internal flooding. See Part 8 for screening and detailed PRA.
	Seiche	This hazard is included under external flooding.
	Storm surge	This hazard is included under external flooding.
	Tsunami	This hazard is included under external flooding and seismic events. See Part 5 and Part 8 for screening and detailed PRA.
	Waves	This hazard is included under external flooding.

Table 6-B-1 List of Hazards for Consideration (Cont'd)

Hazard Group [Note (1)]	Hazard	Remarks [Notes (2), (3), (4)]
Snow	Snow	Plants are designed for higher loading. Regional climatology influences plant-specific susceptibility. Snowmelt causing river flooding can be considered under that flood hazard.
	Avalanche (snow)	This hazard can be excluded for most nuclear plant sites; confirm through walkdown.
Transportation accidents	Aircraft impacts	This hazard is site specific and requires detailed study.
	Fog	Fog could increase the frequency of manmade hazard involving surface vehicles or aircraft; accident data should include the effects.
	Ship impact	This hazard is site specific and requires detailed study.
	Vehicle impact	This hazard is plant specific and requires detailed study.
	Railcar impact	This hazard is plant specific and requires detailed study.
	Vehicle, railway car or ship explosion	This hazard is plant specific and requires detailed study.
Site-generated missiles	Turbine-generated missiles	This hazard is a plant-specific configuration issue.
	Other internally-generated missiles	This hazard is a plant-specific configuration issue.
Volcanic activity	Volcanic activity	This hazard can be excluded for most sites; however, distant impacts of an event may need to be considered (e.g., ash fallout, seismic events).

NOTES:
(1) In accordance with the limitation noted in Section 1-1.2, the occurrence of any listed hazard that results from sabotage or terrorism is excluded from consideration.
(2) The statements in the Remarks column have been typical of past approaches.
(3) The screening guidance provided here only addresses screening out of hazards using the criteria in SR EXT-B1 (and SR EXT-B2, if applicable). The remark "The hazard is site specific and requires detailed study" should not be taken to imply that a PRA using the requirements in Part 7, Part 8, or Part 9 of this Standard is required. Rather, detailed study could be limited to demonstrating that the hazard can be screened out using the criteria in SR EXT-C1.
(4) The idea behind the screening remark that a given hazard is screened because it is "included under" or "covered by" another hazard is that it is not evaluated separately but is inherently included in another data set.
(5) See Part 8 for screening and detailed PRA of External Flooding.

6-B.1 REFERENCES

The following is a list of publications referenced in this Appendix.

[6-B-1] NUREG/CR-2300, "PRA Procedures Guide: A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants," J. W. Hickman et al., American Nuclear Society (ANS) and Institute of Electrical and Electronic Engineers (IEEE), 1983; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[6-B-2] NUREG-1407, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities," 1991; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[6-B-3] IAEA Safety Standards Series No. SSG-3, "Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants," 2010; International Atomic Energy Agency (IAEA), Vienna International Centre, 1400 Vienna, Austria

[6-B-4] NUREG/CR-5042, and UCID-21223, "Evaluation of External Hazards to Nuclear Power Plants in the United States," C. Y. Kimura and R. J. Budnitz, Lawrence Livermore National Laboratory (LLNL), 1987; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[6-B-5] EPRI 1022997, "Identification of External Hazards for Analysis in Probabilistic Risk Assessment," 2011; Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[6-B-6] EPRI 3002005287, "Identification of External Hazards for Analysis in Probabilistic Risk Assessment," 2015; Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[6-B-7] Technical Report ASAMPSA_E /WP21/D21.2/2017-41, "List of External Hazards to Be Considered in ASAMPSA_E," K. Decker and H. Brinkman, 2016; University of Vienna, http://asampsa.eu/

PART 7
REQUIREMENTS FOR HIGH WIND AT-POWER PRA

Section 7-1
Overview of High Wind At-Power PRA Requirements

7-1.1 PRA SCOPE

Part 7 states the requirements for a Level 1 analysis of the core damage frequency (CDF) and large early release frequency (LERF) of the high wind (HW) hazard group while at-power.

7-1.2 COORDINATION WITH OTHER PARTS OF THIS STANDARD

This Part is intended to be used in conjunction with Parts 1 and 2 of this Standard. A PRA developed in accordance with the internal events documented in Part 2 provides the starting point for the development of the high wind PRA (HWPRA) models. The specific HWs considered in this Standard are tropical cyclones, straight winds, and tornadoes. Such HWs may produce or be accompanied by other hazards, such as wind-driven storm surge from tropical cyclones or extratropical storms, and the rain associated with HW events may produce local flooding. Consideration of these correlated hazards will require coordination with other Parts of this Standard.

HWs are distinguished by their wind speeds and ability to produce damage to structures, systems, and components (SSCs) at the plant. Winds that are not "high winds" are those that are well below wind design standards for SSCs and are not considered in Part 7 because they should not produce meaningful damage to plant SSCs. The distinction of what lower-bound wind speed (V_L) constitutes the HW threshold for a site is the starting point for the Part 7 HWPRA. The primary impact associated with wind speeds less than V_L would be incorporated in Part 2, Internal Events, such as weather-induced loss of off-site power (LOOP) events. These events fall within the scope of Part 2 and should be included in the plant internal-events model.

(The text presented in **blue font** in this Standard comprise hyperlinks to enable efficient access to referenced sections and elements, requirements, notes, references, etc.)

Section 7-2
High Wind At-Power PRA Technical Elements and Requirements

There are three technical elements in the HWPRA:

(a) Wind Hazard Analysis (WHA)

(b) Wind Fragility Analysis (WFR)

(c) Wind Plant Response Analysis (WPR)

The technical requirements for the Wind Hazard Analysis, Wind Fragility Analysis, and Wind Plant Response Analysis technical elements for the HW hazards are stated in Sections 7-2.1, 7-2.2, and 7-2.3, respectively.

The nonmandatory appendix (NMA) provides discussion and a number of references regarding HW hazard methods that have been utilized.

7-2.1 WIND HAZARD ANALYSIS (WHA)

The objectives of the Wind Hazard Analysis are

(a) to develop the reference wind speed parameters, establish the range of wind speeds that cover the failure frequency contributions to the HWPRA, and provide justification for grouping individual wind hazards in the HWPRA

(b) to determine which wind hazard types affect the site and, accordingly, which wind hazard types can be screened out

(c) to perform a probabilistic wind hazard analysis (PWHA) for each wind hazard that has not been screened out

(d) to include and propagate aleatory and epistemic uncertainties in each step of the Wind Hazard Analysis

(e) to document the Wind Hazard Analysis so as to provide traceability of the work

The primary output of the Wind Hazard Analysis is the frequency of occurrence of the reference wind speed at the site for each wind hazard that has not otherwise been screened out, including a definition of how the reference wind speed is measured (e.g., 3-sec. gust, mean hourly value, etc.). The reference wind speed is the independent HW hazard variable. All other HW effects, such as wind pressure, atmospheric pressure change (APC), and wind-generated missiles, are predicated on the reference wind speed developed in the Wind Hazard Analysis.

Table 7-2.1-1 provides the High Level Requirements (HLRs) for Wind Hazard Analysis. Individual HLRs are specified for each of the three wind hazard types: straight winds, tropical cyclones, and tornadoes

HLR-WHA-A allows for optional screening out of tropical cyclones, straight winds, and tornadoes. If any of these HW hazard types are screened out under the Supporting Requirements (SRs), then the screened out hazards and their associated effects need not be further evaluated in the HWPRA.

The size of the HW hazard relative to individual SSCs and the broader site areas where missiles can be generated are important for hazards that are narrow in width, such as tornadoes. Therefore, the SRs for tornado hazard development require consideration of the target size and how the hazard frequencies are to be used in the Wind Fragility Analysis.

Table 7-2.1-1 High Level Requirement for Wind Hazard Analysis (WHA)

Designator	Requirement
HLR-WHA-A	Screening out tropical cyclones, straight winds, and tornadoes, as applicable to the site, shall use wind data, site, and plant characteristics.
HLR-WHA-B	The frequencies of wind speeds at the site shall be based on PWHA.
HLR-WHA-C	The PWHA for straight-wind speeds (e.g., thunderstorms and extratropical cyclones) at the site shall represent applicable regional and site-specific information.
HLR-WHA-D	The PWHA for tropical cyclones shall represent applicable regional and site-specific information.
HLR-WHA-E	The PWHA for tornadoes shall represent applicable regional and site-specific information.

Table 7-2.1-1 High Level Requirement for Wind Hazard Analysis (WHA) (Cont'd)

Designator	Requirement
HLR-WHA-F	Aleatory and epistemic uncertainties in the Wind Hazard Analysis shall be identified, characterized, propagated, and included in the final quantification of hazard estimates for the site.
HLR-WHA-G	Documentation of the Wind Hazard Analysis shall provide traceability of the work.

Table 7-2.1-2 Supporting Requirements for HLR-WHA-A

Screening out of tropical cyclones, straight winds, and tornadoes, as applicable to the site, shall use wind data, site, and plant characteristics (HLR-WHA-A).

Index No. WHA-A	Capability Category I	Capability Category II
WHA-A1	COMPILE a list of HW hazards, including combinations of wind hazards that are applicable to the site. Examples of potentially relevant HW hazards include but are not necessarily limited to *(a)* straight wind *(b)* tropical cyclone *(c)* tornado *(d)* wind-driven rain	
WHA-A2	COLLECT current data and information for the site and region.	
WHA-A3	USE the probabilistic screening criteria SCR-1 in Table 1-1.8-1 and the requirements of HLR-EXT-C and HLR-EXT-D in Part 6 when screening out straight winds from the Wind Hazard Analysis. This can use a demonstrably conservative assessment (or a realistic assessment that meets all requirements of Part 7).	
WHA-A4	ENSURE one of the following conditions is met when screening out tropical cyclone (hurricane or typhoon) HW hazards from the Wind Hazard Analysis: *(a)* SATISFY SCR-3 in Table 1-1.8-1 by showing that the site is sufficiently far away from the nearest tropical cyclone-prone coast to screen out tropical cyclone (hurricane or typhoon) HW hazards from the Wind Hazard Analysis. *(b)* Using a demonstrably conservative probabilistic assessment (or a realistic assessment that meets all requirements of Part 7), SATISFY the hazard screening criteria SCR-1 in Table 1-1.8-1 and the requirements of HLR-EXT-C and HLR-EXT-D in Part 6.	
WHA-A5	ENSURE one of the following conditions is met when screening out tornado HW hazards from the Wind Hazard Analysis: *(a)* SATISFY SCR-3 in Table 1-1.8-1 by showing that, for a broad region surrounding the site, tornadoes have not occurred and the meteorological conditions for tornado genesis do not exist. *(b)* Using demonstrably conservative probabilistic assessment (or a realistic assessment that meets all requirements of Part 7), SATISFY the hazard screening criteria SCR-1 in Table 1-1.8-1 and the requirements of HLR-EXT-C and HLR-EXT-D in Part 6.	
WHA-A6	Using a demonstrably conservative assessment (or a realistic assessment that meets all applicable requirements of Part 7), ENSURE the total risk of all HW hazards probabilistically screened out does not exceed the screening criteria SCR-1 in Table 1-1.8-1 or JUSTIFY use of alternative criteria.	
WHA-A7	CONFIRM that the HW hazard screening correctly represents the as-built, as-operated configuration of the plant by performing plant walkdown(s) and review of plant information.	

Table 7-2.1-3 Supporting Requirements for HLR-WHA-B

The frequencies of wind speeds at the site shall be based on PWHA (HLR-WHA-B).

Index No. WHA-B	Capability Category I	Capability Category II
WHA-B1	DEFINE the reference wind-speed parameters for each HW hazard and justify any deviations from the applicable national wind-loading standard.	
WHA-B2	When calculating reference wind speeds from raw wind-speed data, USE currently accepted wind-speed-conversion methods.	
WHA-B3	ENSURE that the Wind Hazard Analysis includes the effect of short duration wind events, such as thunderstorms and tornadoes, in the derivation of the resulting wind-speed frequencies.	
WHA-B4	SPECIFY a V_L magnitude for the PWHA that provides assurance that potential HW damage to SSCs identified in HLR-WFR-A are included.	
WHA-B5	ENSURE that the discretization of the HW-speed hazard curves into intervals produces sufficient information for accurate wind frequency and plant-response determination over the full range of wind speeds ≥ V_L.	
WHA-B6	In developing the HW hazard results for use in accident sequence quantification, EXTEND the HW speed to large-enough values so that the truncation does not significantly affect the final numerical results (e.g., on metrics such as CDF and LERF) or the delineation and ranking of HW-initiated sequences.	

Table 7-2.1-4 Supporting Requirements for HLR-WHA-C

The PWHA for straight-wind speeds (e.g., thunderstorms and extratropical cyclones) at the site shall represent applicable regional and site-specific information (HLR-WHA-C).

Index No. WHA-C	Capability Category I	Capability Category II
WHA-C1	IDENTIFY anemometer stations near the site and EVALUATE the applicability and quality of the wind data at each station for use in the PWHA.	
WHA-C2	In analyzing wind station data, ENSURE that the data are updated, as necessary, to the reference wind speed defined in SR WHA-B1.	
WHA-C3	ANALYZE straight-wind data without separation of thunderstorm from nonthunderstorm data.	ANALYZE thunderstorm and nonthunderstorm data separately to produce the straight-wind hazard frequencies.
WHA-C4	JUSTIFY the distribution used for the wind-speed probability in the analysis and its use in the context of rare straight-wind phenomena.	
WHA-C5	JUSTIFY the method used to produce the site-specific straight-wind frequencies from wind data records analyzed.	
WHA-C6	COMPARE the straight-wind-speed frequencies and uncertainties with reference to available data. If no data are available, JUSTIFY the reasonableness of the wind-speed frequencies and uncertainties used.	COMPARE the straight-wind-speed frequencies and uncertainties with reference to the most recent published data. IDENTIFY areas of significant differences.

Table 7-2.1-5 Supporting Requirements for HLR-WHA-D

The PWHA for tropical cyclones shall represent applicable regional and site-specific information (HLR-WHA-D).

Index No. WHA-D	Capability Category I	Capability Category II
WHA-D1	DEVELOP site-specific PWHA tropical cyclone wind-speed frequencies by using one of the following methods: *(a)* an analysis using data from a study, publication, or standard or *(b)* calculations with a probabilistic hurricane model that includes frequency and intensity data, spatial modeling of storm tracks, a validated wind field model, a validated wind pressure relationship, and validated inland decay model.	
WHA-D2	COMPARE the tropical cyclone wind-speed frequencies and uncertainties with available reference data. If no data are available, JUSTIFY the reasonableness of the wind-speed frequencies and uncertainties used.	COMPARE the tropical cyclone wind-speed frequencies and uncertainties with reference to most recent published data. IDENTIFY areas of significant differences.

Table 7-2.1-6 Supporting Requirements for HLR-WHA-E

The PWHA for tornadoes shall represent applicable regional and site-specific information (HLR-WHA-E).

Index No. WHA-E	Capability Category I	Capability Category II
WHA-E1	DEVELOP site-specific PWHA tornado wind-speed frequencies by using one of the following methods: *(a)* an analysis using data from a study, publication, or standard that meets SR WHA-E2 or *(b)* calculations using a probabilistic tornado hazard model that meets SR WHA-E2.	
WHA-E2	ENSURE that the PWHA tornado wind-speed frequencies include *(a)* frequency analysis and intensity data that represent the site and regional tornado climatological risk *(b)* analysis of and corrections for tornado reporting limitations and uncertainties *(c)* tornado path length and width correlations to tornado intensity *(d)* variation of tornado intensity along the path length and across the path width *(e)* probabilistic models of tornado wind speed given damage intensity	
WHA-E3	ENSURE that the tornado region used in the site analysis is reasonably homogeneous and sufficiently broad to adequately represent the tornado climatology at the site and the risks associated with these rare events.	
WHA-E4	ENSURE that the tornado analysis accounts for target sizes when considering the effects of wind pressure, APC, and wind-borne missiles.	
WHA-E5	COMPARE the tornado wind-speed frequencies and uncertainties with reference to available data. If no data are available, JUSTIFY the reasonableness of the wind-speed frequencies and uncertainties used.	COMPARE the tornado wind-speed frequencies and uncertainties with reference to most recent published data. IDENTIFY areas of significant differences.

Table 7-2.1-7 Supporting Requirements for HLR-WHA-F

Aleatory and epistemic uncertainties in the Wind Hazard Analysis shall be identified, characterized, propagated, and included in the final quantification of hazard estimates for the site (HLR-WHA-F).

Index No. WHA-F	Capability Category I	Capability Category II
WHA-F1	IDENTIFY assumptions and sources of uncertainty for each HW hazard.	
WHA-F2	CHARACTERIZE important sources of uncertainty for each HW hazard, such as using sensitivity studies related to alternative data, models, and methods.	
WHA-F3	ESTIMATE the aleatory and epistemic uncertainties that are risk-significant contributors to the HW frequency quantifications.	PROPAGATE the aleatory and epistemic uncertainties that are risk-significant contributors to the HW frequency quantifications.

Table 7-2.1-8 Supporting Requirements for HLR-WHA-G

Documentation of the Wind Hazard Analysis shall provide traceability of the work (HLR-WHA-G).

Index No. WHA-G	Capability Category I	Capability Category II
WHA-G1	DOCUMENT the process used in the Wind Hazard Analysis specifying the input, the applied methods, and the results. Address the following and other details needed to fully document how the SRs are satisfied: *(a)* The process used to identify and screen out HW hazard types *(b)* The approach used to perform the Wind Hazard Analysis *(c)* The data, models, and methods used for determining the HW hazard curves *(d)* The basis for including or excluding data, models, and methods in the analysis *(e)* All assumptions	
WHA-G2	DOCUMENT the sources of model uncertainty for each HW hazard, the related assumptions, and reasonable alternatives (as identified in SRs SY-A25 and SY-B14) associated with the Systems Analysis.	

7-2.2 WIND FRAGILITY ANALYSIS (WFR)

The objective of the Wind Fragility Analysis is to identify those SSCs that are vulnerable to the effects of HWs and to derive site-specific wind fragilities. HW effects include

(a) wind pressure and APC
(b) wind-generated missiles
(c) structural interactions
(d) wind-driven rain
(e) correlated hazard effects

These effects are the physical loadings that can result from HW hazards. Wind Fragility Analysis includes the appropriate wind effects for each wind hazard type that affects the site.

The process used to develop these wind fragilities is referred to as probabilistic wind fragility analysis (PWFA). The key steps in this process are to

(a) identify SSCs that are vulnerable to the effects of HWs and include those SSCs whose failure may contribute to the plant CDF and LERF

(b) evaluate SSCs and their potential failure modes and characterize potential wind-generated missiles by conducting a walkdown of the site

(c) assess wind pressure and APC effects, wind-generated missile effects, structural interaction effects, and wind-driven rain effects

(d) include correlated hazard effects, as appropriate, to the site

(e) justify the methodologies used to screen out SSCs, wind effects, and failure modes

(f) perform a PWFA for each SSC, wind effect, and failure mode not screened out

The output of the PWFA is the conditional probabilities of failure (wind fragilities) as a function of the reference wind speed, which is the independent hazard variable in HWPRAs. The reference wind speed used in the Wind Fragility Analysis must match the reference wind speed defined in the applicable requirements of the Wind Hazard Analysis technical element for each wind hazard type.

All wind effects (wind pressure, APC, wind-generated missiles, wind-driven rain) in the Wind Fragility Analysis are based on the reference wind speed. All correlated hazard effects that are identified and analyzed as part of the HWPRA scope are also based on the reference wind speed. This basis ensures that the major cause of the correlated effects is analyzed consistently within the HWPRA and in the computation of CDF and LERF.

The hierarchy of wind hazard type, wind effects by hazard type, and potential failure modes by wind effect are fundamental to the organization of PWFA. Wind effects depend on the wind hazard type. For example, APC effects occur with tornadoes. Wind-generated missile effects differ with wind hazard type. Missiles produced from straight winds and tropical cyclones have different impact probabilities and impact speeds due to differences in the wind field characteristics. The frequency, intensity, and duration of wind-driven rain are also dependent on the wind hazard type.

HW fragilities are generally dependent on the wind effect and may be developed either in combination with multiple wind effects or separately by individual wind effect. Justification is required in Wind Fragility Analysis for aggregating effects and wind fragilities across wind hazard types.

Determining the appropriate analysis for the correlation of wind fragilities across wind effects and failure modes is an inherent challenge in PWFA due to the complexity of the analysis and the potentially large numbers of SSCs that may be impacted. The analyst must assess the important fragility correlations that should be addressed in the HWPRA.

Table 7-2.2-1 High Level Requirements for Wind Fragility Analysis (WFR)

Designator	Requirement
HLR-WFR-A	The Wind Fragility Analysis shall incorporate wind fragilities of SSCs for each wind hazard type whose failure may contribute to core damage or large early release.
HLR-WFR-B	The Wind Fragility Analysis shall incorporate the data and findings of walkdown(s) to establish or confirm as-built, as-operated site conditions.
HLR-WFR-C	Fragility screening shall be based on a structured process for individual SSCs, wind effects, and failure modes.
HLR-WFR-D	The PWFA shall include wind pressure and APC effects.
HLR-WFR-E	The PWFA shall include wind-generated missile effects.
HLR-WFR-F	The PWFA shall include structural interaction effects.
HLR-WFR-G	The PWFA shall include wind-driven rain effects if relevant to the plant.
HLR-WFR-H	Aleatory and epistemic uncertainties in each step of the Wind Fragility Analysis shall be identified, propagated, and displayed in the quantification of wind fragilities.
HLR-WFR-I	Documentation of the Wind Fragility Analysis shall provide traceability of the work.

Table 7-2.2-2 Supporting Requirements for HLR-WFR-A

The Wind Fragility Analysis shall incorporate wind fragilities of SSCs for each wind hazard type whose failure may contribute to core damage or large early release (HLR-WFR-A).

Index No. WFR-A	Capability Category I	Capability Category II
WFR-A1	INCLUDE in the scope of the Wind Fragility Analysis those SSCs and associated failure modes identified in the Wind Plant Response Analysis and any structures that are not included in the plant-response model but that enclose or protect those SSCs. See HLR-WPR-C1, HLR-WPR-C2, HLR-WPR-C3, and HLR-WPR-C4.	
WFR-A2	DEVELOP wind fragilities that are (*a*) based on the reference wind speed for each HW hazard, (*b*) site-specific, and (*c*) SSC-specific.	
WFR-A3	ENSURE that the wind fragilities cover the range of wind speeds developed in SRs WHA-B5 and WHA-B6.	
WFR-A4	ENSURE that the SSC failure modes that are not screened out are included for each wind loading effect.	
WFR-A5	When multiple effects and/or failure modes are aggregated into a single fragility, JUSTIFY the method used for the aggregation.	
WFR-A6	When the same wind fragilities are used for different wind hazards, JUSTIFY the basis for not using wind-hazard-specific fragilities.	
WFR-A7	DEVELOP the HW fragility correlations of wind-induced SSC failures, if applicable, and ASSESS the correlations for their impact on HWPRA results and insights.	
WFR-A8	ADDRESS the effects of coexistent hazards on the fragilities that are included in the HWPRA scope, if applicable.	

Table 7-2.2-3 Supporting Requirements for HLR-WFR-B

The Wind Fragility Analysis shall incorporate the data and findings of walkdown(s) to establish or confirm as-built, as-operated site conditions (HLR-WFR-B).

Index No. WFR-B	Capability Category I	Capability Category II
WFR-B1	COLLECT information about as-built, as-operated site characteristics relevant to the Wind Fragility Analysis, such as construction characteristics and potential failure modes (e.g., structural interactions and missile effects) related to plant SSCs, for each wind effect by conducting a walkdown.	
WFR-B2	ENSURE that for those SSCs included in the HWEL, SSC supporting elements (e.g., associated piping, conduits, vents, supports, and other components required to support functionality) are identified in the walkdown and are included in the Wind Fragility Analysis.	
WFR-B3	In evaluating SSCs that are screened out for one or more wind failure modes in SR WFR-A4 and HLR-WFR-C, CONFIRM that the assumptions used in the screening analysis are consistent with the observations from the walkdown.	
WFR-B4	COMPILE the numbers, types, and locations of potential missiles that may cause individual SSCs to fail (e.g., via plant survey).	
WFR-B5	ENSURE that the missile characterization is consistent with the missile fragility methodology requirements under SRs WFR-E3, WFR-E4, and WFR-E5.	
WFR-B6	ESTIMATE the number of potential missiles and their locations for different plant-operating states, such as outage and nonoutage modes.	

Table 7-2.2-4 Supporting Requirements for HLR-WFR-C

Fragility screening shall be based on a structured process for individual SSCs, wind effects, and failure modes (HLR-WFR-C).

Index No. WFR-C	Capability Category I	Capability Category II
WFR-C1	If an SSC is screened out for wind pressure effects and/or APC effects, JUSTIFY the methodology used and the basis for the screening-out evaluation.	
WFR-C2	If wind-generated missile effects are screened out for an SSC, JUSTIFY the basis for the screening-out evaluation.	
WFR-C3	If structural-interaction effects are screened out for an SSC, JUSTIFY the basis for the screening-out evaluation.	
WFR-C4	If wind-driven rain effects are screened out for an SSC, JUSTIFY the basis for the screening-out evaluation.	

Table 7-2.2-5 Supporting Requirements for HLR-WFR-D

The PWFA shall include wind pressure and APC effects (HLR-WFR-D).

Index No. WFR-D	Capability Category I	Capability Category II
WFR-D1	JUSTIFY the methods used for developing wind pressure load effects if they deviate from applicable national wind-loading standards.	
WFR-D2	JUSTIFY the methods used for developing APC load effects, including methods for combining wind pressure and APC loads.	
WFR-D3	ENSURE that differences in wind design loads are included when the SSC design information and applicable codes are compared with current wind standards and codes.	

Table 7-2.2-5 Supporting Requirements for HLR-WFR-D (Cont'd)

The PWFA shall include wind pressure and APC effects (HLR-WFR-D).

Index No. WFR-D	Capability Category I	Capability Category II
WFR-D4	If the SSC is a flexible structure, ENSURE that the dynamic response characteristics are included in the wind effects.	
WFR-D5	EVALUATE the site for potential topographic effects according to applicable national standards or other published methodologies and, if applicable, ENSURE that the wind pressure effects represent topographic speed-ups (local increases in wind speed due to local topographical factors).	
WFR-D6	ASSESS SSCs for potential wind pressure load effects including shielding and INCLUDE factors for these potential effects in the fragility calculation, if applicable.	

Table 7-2.2-6 Supporting Requirements for HLR-WFR-E

The PWFA shall include wind-generated missile effects (HLR-WFR-E).

Index No. WFR-E	Capability Category I	Capability Category II
WFR-E1	USE the site-specific wind hazard characteristics and their associated wind fields for developing wind-generated missile effects.	
WFR-E2	JUSTIFY the basis for using missile effects that are not wind hazard–specific.	
WFR-E3	GROUP the missile types for fragility evaluation using the numbers and types of missiles surveyed in SRs WFR-B4, WFR-B5, and WFR-B6.	
WFR-E4	DESCRIBE how missiles from structure sources, including building envelope sources, building contents, and rooftop missiles are quantified and included in the missile analysis.	
WFR-E5	When missile sources are excluded from the analysis because they are located too far from the nearest target SSCs, JUSTIFY the basis.	
WFR-E6	When the missile impact and damage methodology uses a scaling approach based on SSC dimensions, area, or volume, JUSTIFY the approach.	
WFR-E7	DEMONSTRATE that the missile impact and damage methodology produces stable numerical results for the missile effects over the range of wind speeds.	
WFR-E8	SPECIFY the assumptions and analysis methods in the missile effects analysis, including *(a)* the spatial effects of the plant layout, topography, SSC locations, and missile numbers and sources *(b)* wind field characteristics *(c)* missile injection, aerodynamics, and trajectory analysis *(d)* missile impact and damage to SSCs *(e)* multiple missile generation in a wind hazard event	SPECIFY the assumptions and analysis methods in the missile effects analysis, including *(a)* the spatial effects of the plant layout, topography, SSC locations, and missile numbers and sources *(b)* shielding structures and features *(c)* wind field characteristics *(d)* missile injection, aerodynamics, and trajectory analysis, including ricochet into SSCs, if appropriate *(e)* missile impact and damage to SSCs *(f)* multiple missile generation in a wind hazard event ENSURE that the site-specific missile impact and damage calculations include *(a)* site-specific wind hazard path sizes and path direction distributions *(b)* missile type-dependent aerodynamics *(c)* missile damage analysis methods that depend on missile type ENSURE that the method captures risk-significant SSCs and site-specific features.
WFR-E9	SPECIFY the missile hit/damage criterion for each SSC.	

Table 7-2.2-6 Supporting Requirements for HLR-WFR-E (Cont'd)

The PWFA shall include wind-generated missile effects (HLR-WFR-E).

Index No. WFR-E	Capability Category I	Capability Category II
WFR-E10	DESCRIBE how the correlations of missile hit/damage to multiple SSCs in the same wind event are analyzed.	
WFR-E11	ENSURE that variations in missile populations including outage/non-outage conditions and plant configuration changes are included in the missile impact and damage analysis.	

Table 7-2.2-7 Supporting Requirements for HLR-WFR-F

The PWFA shall include structural interactions effects (HLR-WFR-F).

Index No. WFR-F	Capability Category I	Capability Category II
WFR-F1	DEFINE the methodology used for structural interaction analyses.	
WFR-F2	INCLUDE potential structural interaction effects from the failure of chimneys, stacks, exhausts, towers, poles, walls, roof structures, and other structures and components on SSCs included in the HWEL.	

Table 7-2.2-8 Supporting Requirements for HLR-WFR-G

The PWFA shall include wind-driven rain effects if relevant to the plant (HLR-WFR-G).

Index No. WFR-G	Capability Category I	Capability Category II
WFR-G1	DEFINE the methodology used for wind-driven rain effects.	
WFR-G2	INCLUDE the wind-driven rainwater entry paths that may lead to water drip, splash, and/or rain onto potentially risk-significant SSCs.	

Table 7-2.2-9 Supporting Requirements for HLR-WFR-H

Aleatory and epistemic uncertainties in each step of the Wind Fragility Analysis shall be identified, propagated, and displayed in the quantification of wind fragilities (HLR-WFR-H).

Index No. WFR-H	Capability Category I	Capability Category II
WFR-H1	IDENTIFY aleatory and epistemic uncertainties to be evaluated in the Wind Fragility Analysis.	
WFR-H2	CHARACTERIZE the important sources of uncertainty in the Wind Fragility Analysis (e.g., using uncertainty analysis or sensitivity studies).	
WFR-H3	CALCULATE the fractile and mean fragilities considering aleatory and epistemic uncertainties.	

Table 7-2.2-10 Supporting Requirements for HLR-WFR-I

Documentation of the Wind Fragility Analysis shall provide traceability of the work (HLR-WFR-I).

Index No. WFR-I	Capability Category I	Capability Category II
WFR-I1	DOCUMENT the process used to perform the Wind Fragility Analysis including a description of each of the following as applicable: *(a)* the methodologies used to quantify the HW fragilities of SSCs, along with assumptions; *(b)* a detailed set of SSC fragility values or fragility curves that includes the method of analysis, the significant failure mode(s), the sources of information, and the location of each SSC; *(c)* the screening methodology; *(d)* the basis for screening out any SSC depending on the generic HW capacity; *(e)* the method of identifying SSC failure mechanisms, the identified failure mechanisms, and the associated failure modes; *(f)* the treatment of wind pressure and APC effects, wind-generated missile effects, structural interactions effects, and wind-driven rain effects if relevant to the plant; *(g)* walkdown observations and conclusions; and *(h)* the results of the fragility evaluation.	
WFR-I2	DOCUMENT the sources of model uncertainty, the related assumptions, and reasonable alternatives (as identified in SRs SY-A25 and SY-B14) associated with the Wind Fragility Analysis.	

7-2.3 WIND PLANT RESPONSE ANALYSIS (WPR)

The objectives of the Wind Plant Response Analysis are to

(a) develop a HW plant-response model (e.g., using the internal events model as a starting point)

(b) develop accident sequences based on the plant configuration, the relevant initiating events and the resultant failures

(c) integrate the Wind Hazard Analysis and the Wind Fragility Analysis with the plant-response model to estimate CDF and LERF

Table 7-2.3-1 High Level Requirements for Wind Plant Response Analysis (WPR)

Designator	Requirement
HLR-WPR-A	The HW plant-response model shall include HW-induced initiating events that cause risk-significant accident sequences and/or risk-significant accident progression sequences.
HLR-WPR-B	The HW plant-response model shall include HW-induced SSC failures, non-HW induced SSC failures, unavailabilities, human errors, and multi-unit effects that may lead to core damage or large early release.
HLR-WPR-C	The list of SSCs selected for Wind Fragility Analysis shall include the SSCs that contribute to accident sequences included in the HW plant-response model.
HLR-WPR-D	Human actions credited in the HWPRA shall consider HW-specific challenges to human performance.
HLR-WPR-E	The analysis to quantify CDF and LERF shall integrate the HW hazard, the HW fragilities, and the HW plant response, including uncertainties on a reactor-year basis.
HLR-WPR-F	Documentation of the Wind Plant Response Analysis and quantification analysis shall provide traceability of the work.

Table 7-2.3-2 Supporting Requirements for HLR-WPR-A

The HW plant-response model shall include HW-caused initiating events that cause risk-significant accident sequences and/or risk-significant accident progression sequences (HLR-WPR-A).

Index No. WPR-A	Capability Category I	Capability Category II
WPR-A1	IDENTIFY HW-induced initiating events caused directly by the HW event by using a process that addresses the unique aspects of each applicable hazard type (e.g., straight wind, tornado, and tropical cyclone).	
WPR-A2	IDENTIFY initiating events caused directly or indirectly by the HW event, including initiating events associated with changes in the plant mode (e.g., plant shutdown) or proceduralized plant reconfigurations prior to shutdown (if applicable) due to the HW event.	
WPR-A3	ENSURE the initiating events included in the Wind Plant Response Analysis represent industry experience (e.g., through review of plant-specific response to past HW events or warnings, industry operating experience, and other available HW risk evaluations for nuclear plants).	
WPR-A4	Using a systematic process and a review of relevant industry experience, IDENTIFY HW-induced hazard events resulting from coexistent hazards that can induce initiating events or SSC failures modeled in the HWPRA.	
WPR-A5	INCLUDE in the plant-response model the initiating events, identified in SRs WPR-A1, WPR-A2, and WPR-A3.	

Table 7-2.3-3 Supporting Requirements for HLR-WPR-B

The HW plant-response model shall include HW-induced SSC failures, non-HW-induced SSC failures, unavailabilities, human errors, and multi-unit effects that may lead to core damage or large early release (HLR-WPR-B).

Index No. WPR-B	Capability Category I	Capability Category II
WPR-B1	USE the accident sequences and the systems logic model from the at-power, internal-event PRA models as the basis of the plant-response model.	
WPR-B2	ENSURE that significant deficiencies identified during the peer review for the internal-events PRA and the other PRAs that are relevant to the results of the HWPRA are resolved and incorporated into the development of the Wind Plant Response Analysis.	
WPR-B3	INCLUDE HW-induced failures representing failure modes of interest in the HWPRA plant-response model.	
WPR-B4	MODEL the fragility correlation of wind-induced SSC failures if applicable. JUSTIFY the correlation approach used.	
WPR-B5	ASSESS the safe and stable end state of the HW-induced accident sequences in accordance with SR SC-A5 Capability Category I (CC-I) to confirm that sustained impacts on plant accessibility and emergency-response capability do not invalidate the assumed mission time.	ASSESS the safe and stable end state of the HW-induced accident sequences in accordance with SR SC-A5 Capability Category II (CC-II) to confirm that sustained impacts on plant accessibility and emergency-response capability do not invalidate the assumed mission time.

Table 7-2.3-3 Supporting Requirements for HLR-WPR-B (Cont'd)

The HW plant-response model shall include HW-induced SSC failures, non-HW-induced SSC failures, unavailabilities, human errors, and multi-unit effects that may lead to core damage or large early release (HLR-WPR-B).

Index No. WPR-B	Capability Category I	Capability Category II
WPR-B6	For PRA logic models developed for the HWPRA, SATISFY the following requirements, consistent with CC- I requirements in Part 2 (if applicable): *(a)* Initiating Event Analysis per HLR-IE-A and HLR-IE-B *(b)* Accident Sequence Analysis per HLR-AS-A and HLR-AS-B *(c)* Success Criteria per HLR-SC-A and HLR-SC-B. *(d)* Systems Analysis per HLR-SY-A and HLR-SY-B *(e)* Data Analysis per HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D ENSURE the following are represented: *(a)* HW-induced SSC failures, *(b)* SSC unavailabilities and failures not induced by the HW event, and *(c)* Human actions associated with HW response (including HW-related actions not included within the internal-events model) that can give rise to risk-significant accident sequences or risk-significant accident progression sequences.	For PRA logic models developed for the HWPRA, SATISFY the following requirements, consistent with CC- II requirements in Part 2 (if applicable): *(a)* Initiating Event Analysis per HLR-IE-A and HLR-IE-B *(b)* Accident Sequence Analysis per HLR-AS-A and HLR-AS-B *(c)* Success Criteria per HLR-SC-A and HLR-SC-B. *(d)* Systems Analysis per HLR-SY-A and HLR-SY-B *(e)* Data Analysis per HLR-DA-A, HLR-DA-B, HLR-DA-C, and HLR-DA-D ENSURE the following are represented: *(a)* HW-induced SSC failures, *(b)* SSC unavailabilities and failures not induced by the HW event, and *(c)* Human actions associated with HW response (including HW-related actions not included within the internal-events model) that can give rise to risk-significant accident sequences or risk-significant accident progression sequences.
WPR-B7	INCLUDE coexistent hazards that are within the scope of the HWPRA.	
WPR-B8	For sites with multiple units, ASSESS the effects of HWs on other units as it affects the unit under study (e.g., effects on resources and organizational response, shared SSCs, and site accessibility).	

Table 7-2.3-4 Supporting Requirements for HLR-WPR-C

The list of SSCs selected for Wind Fragility Analysis shall include the SSCs that contribute to accident sequences included in the HW plant-response model (HLR-WPR-C).

Index No. WPR-C	Capability Category I	Capability Category II
WPR-C1	DEVELOP an HWEL based on the internal-events PRA model.	
WPR-C2	INCLUDE in the HWEL additional SSCs that are not modeled in the internal-events model but that require evaluation in the HWPRA.	
WPR-C3	AUGMENT the HWEL based on the review of industry HWPRA HWELs, if available.	
WPR-C4	INCLUDE in the HWEL structural interactions (including spatial interactions) due to SSCs that may not be present in the internal-events model.	
WPR-C5	For the SSCs identified in SRs WPR-C1, WPR-C2, WPR-C3, and WPR-C4, IDENTIFY the failure mode(s) of interest for the Wind Fragility Analysis.	

Table 7-2.3-5 Supporting Requirements for HLR-WPR-D

Human actions credited in the HWPRA shall consider HW-specific challenges to human performance (HLR-WPR-D).

Index No. WPR-D	Capability Category I	Capability Category II
WPR-D1	IDENTIFY the human failure events (HFEs) from the baseline (e.g., internal events) PRA and those not included in existing PRA models, including preparatory and recovery actions, that are relevant in the context of the HWPRA.	
WPR-D2	EVALUATE operator actions for performance-shaping factors related to unique aspects of each HW hazard (e.g., straight wind, tornado, and tropical cyclones).	
WPR-D3	For human-response actions relevant to the Wind Plant Response Analysis, SATISFY CC-I requirements in HLR-HR-E of Part 2, except where the requirements are not applicable.	For human-response actions relevant to the Wind Plant Response Analysis, SATISFY CC-II requirements in HLR-HR-E of Part 2, except where the requirements are not applicable.
WPR-D4	For definition and specification of HFEs for human-response actions, SATISFY CC-I requirements in HLR-HR-F of Part 2, except where the requirements are not applicable.	For definition and specification of HFEs for human-response actions, SATISFY CC-II requirements in HLR-HR-F of Part 2, except where the requirements are not applicable.
WPR-D5	REVIEW procedures and sequences of events with plant operations or training personnel to confirm that the interpretation of the procedures relevant to actions credited in the HWPRA is consistent with plant operational and training practices.	
WPR-D6	For treatment of operator actions, SATISFY the requirements in HLR-HR-H, except where the requirements are not applicable.	
WPR-D7	INCLUDE HFEs in the HWPRA plant-response model such that the HFEs represent the impact of human failures at the function, system, train, or component level, as appropriate.	
WPR-D8	ADJUST the credited recovery models based on results of SR WPR-D6. SPECIFY the basis for recovery values, if used (e.g., based on review of procedures and assessment of conditions under which actions will be performed).	
WPR-D9	For developing human error probabilities (HEPs), SATISFY CC-I requirements in HLR-HR-G in Part 2, except where they are not applicable, taking into consideration relevant HW-related effects on human actions. When addressing influencing factors and the timing considerations in SRs HR-G3, HR-G4, and HR-G5 of Part 2, INCLUDE the effect of the HW hazard on the control room and ex-control room human actions, for example, *(a)* additional workload and stress *(b)* environment in which personnel are working (e.g., weather, heat, lighting, radiation) *(c)* HW failures that impact access *(d)* staffing and communications *(e)* lack of cue availability *(f)* effects of HW on mitigation, required response, timing, accessibility, and potential for physical harm *(g)* wind-specific job aids and training	For developing HEPs, SATISFY CC-II requirements in HLR-HR-G in Part 2, except where they are not applicable, taking into consideration relevant HW-related effects on human actions. When addressing influencing factors and the timing considerations in SRs HR-G3, HR-G4, and HR-G5 of Part 2, INCLUDE the effect of the HW hazard on the control room and ex-control room human actions, for example, *(a)* additional workload and stress, *(b)* environment in which personnel are working (e.g., weather, heat, lighting, radiation), *(c)* HW failures that impact access *(d)* Staffing and communications *(e)* lack of cue availability *(f)* effects of HW on mitigation, required response, timing, accessibility, and potential for physical harm *(g)* wind-specific job aids and training

Table 7-2.3-6 Supporting Requirements for HLR-WPR-E

The analysis to quantify CDF and LERF shall integrate the HW hazard, the HW fragilities, and the HW plant response, including uncertainties on a reactor-year basis (HLR-WPR-E).

Index No. WPR-E	Capability Category I	Capability Category II
WPR-E1	In the quantification of CDF and LERF on a reactor-year basis, INTEGRATE the HW hazard, fragility, and systems analyses in the PRA model.	
WPR-E2	ADDRESS overestimation of risk due to rare-event approximations (e.g., where fragilities approach 1.0).	
WPR-E3	ENSURE that the discretization of the wind-speed hazard curves (or other numerical methods used to incorporate the hazard curve in the integration) is appropriate to demonstrate convergence of CDF and LERF (e.g., the size and number of bins used to discretize the hazard curve).	
WPR-E4	When quantifying HW CDF, SATISFY SRs QU-A2, QU-A4, and QU-A5; QU-B1, QU-B2, and QU-B3; QU-B5, QU-B6, QU-B7, QU-B8, QU-B9, and QU-B10; QU-C1, QU-C2, and QU-C3; QU-D1, QU-D2, and QU-D3; QU-D5, QU-D6, and QU-D7; and QU-E1 and QU-E2 in Part 2, except where the requirements are not applicable.	
WPR-E5	USE the hazard curves, wind fragilities, and a point-estimate quantification of the plant-response model to generate point estimates of CDF and LERF.	QUANTIFY the mean and the uncertainties of the CDF and LERF estimates by propagating the uncertainties associated with HW-hazard frequency, HW fragility, and HW plant-response model events through the quantification process.
WPR-E6	In the analysis of LERF, SATISFY CC-I requirements in SRs LE-A2; LE-C2, LE-C3, LE-C4, and LE-C12; LE-D3; LE-E3; and LE-F1 and LE-F2 in Part 2, except where the requirements are not applicable to the HW hazard.	In the analysis of LERF, SATISFY CC-II requirements in SRs LE-A2; LE-C2, LE-C3, LE-C4, and LE-C12; LE-D3; LE-E3; and LE-F1 and LE-F2 in Part 2, except where the requirements are not applicable to the HW hazard.
WPR-E7	IDENTIFY assumptions and sources of uncertainty in the Wind Plant Response Analysis.	
WPR-E8	CHARACTERIZE important sources of uncertainty in the Wind Plant Response Analysis (e.g., using uncertainty analysis or sensitivity studies) and SATISFY SR QU-E1 for each technical element (i.e., Wind Hazard Analysis, Wind Fragility Analysis, and Wind Plant Response Analysis).	

Table 7-2.3-7 Supporting Requirements for HLR-WPR-F

Documentation of the Wind Plant Response Analysis and Quantification Analysis shall provide traceability of the work (HLR-WPR-F).

Index No. WPR-F	Capability Category I	Capability Category II
WPR-F1	DOCUMENT the process used in the Wind Plant Response Analysis and quantification specifying the inputs to the Wind Plant Response Analysis technical element, applied methods and the results. Address the following, as well as other details needed to fully document how the set of SRs are satisfied: *(a)* the specific adaptations made in the internal events PRA model to produce the HWPRA model, and their bases *(b)* those wind-related influences that affect methods, processes, or assumptions used and the identification and quantification of the HFEs/HEPs in accordance with HLR-WPR-D *(c)* the major outputs of an HWPRA, such as CDF, LERF, sequence contributions, initiating-event contributions, uncertainty distributions on CDF and LERF, results of sensitivity studies, and risk-significant contributors consistent with SRs QU-F1, QU-F2, QU-F3, and QU-F4 and LE-G1 and LE-G2 of Part 2, except where the requirements are not applicable.	
WPR-F2	DOCUMENT the sources of model uncertainty, the related assumptions, and reasonable alternatives (as identified in SRs WPR-E7 and WPR-E8) associated with the Wind Plant Response Analysis.	

NONMANDATORY APPENDIX 7-A HIGH WIND NOTES and COMMENTARY

7-A.1 OVERVIEW OF HIGH WIND AT-POWER PRA REQUIREMENTS

The update to Part 7 represents approximately a 20-year period since the last major update regarding HWPRAs. A significant amount of new information, publications, improved national standards, and advances in wind engineering have occurred during this time. Approximately 12 HWPRAs have been performed in the past few years. These studies revealed that HWs contribute more to a plant's CDF and LERF than previously thought (Mironenko and Lovelace, [7-A-1]). A number of papers have documented methods used, insights, and lessons learned from these recent assessments. Resources are listed in Section 7-A.4.

The requirements for this revision to Part 7 were prepared based on the current state of practice for Wind Hazard Analysis, Wind Fragility Analysis, and Wind Plant Response Analysis. The intent of the revision was to update Part 7 by following the state of practice in national wind load documents and recent HWPRAs. The state-of-practice methods and the ensuing requirements applied in writing Part 7 are part of the continuing evolution of the art and science in performing HWPRAs.

The realities of multiple wind-hazard analyses for most sites and multiple wind effects for each hazard make for a broad technical scope for HWPRAs. Plants predating 10 CFR Part 50 Appendix A (General Design Criteria) (NRC, [7-A-2]), frequently lack mature HW design requirements and, as a result, typically possess vulnerable SSCs that are identified in the HW walkdowns.

HW hazard analysis has matured significantly over the past decade. State-of-the-art and state-of-the-practice standards for straight wind (ASCE 7-16, [7-A-3]) and tropical cyclones (NUREG/CR-7005, [7-A-4]) are available to the analyst. However, current standards for tornado wind frequencies tend to lag the state of the art, and the analyst may need to incorporate safety factors in tornado hazard analysis that address documented limitations. Development of a new ASCE standard for tornado hazard wind speed analysis is underway (Phan et al., [7-A-5], [7-A-6]), and additional publications are expected to be released.

The Wind Fragility Analysis requirements in the updated Part 7 of this Standard have been organized by the four primary wind effects—pressure and APC, wind-generated missiles, structural interactions, and wind-driven rain. The analyst may identify additional effects and correlated hazards that are needed in an HWPRA.

Wind-driven rain is an effect that was not mentioned in the previous edition of Part 7. Because many wind hazards are often, but not always, accompanied by intense rain, certain interior electrical equipment may experience a significant amount of rainwater deposition if the building envelope fails during an HW event. Wind-driven rain has been evaluated in several recent HWPRAs as part of a refined analysis to reduce conservatisms (Twisdale et al., [7-A-7]; Vickery et al., [7-A-8]; Lovelace et al., [7-A-9]).

The commentary and notes herein are intended to provide the basis, clarification, and discussion of the HW requirements. All commentary is provided at the SR level.

The goal of the notes and commentary contained in this NMA to Part 7 is to ensure that analysts are apprised of certain known characteristics, challenges, and issues associated with modeling HW hazards, effects, and failure modes. While some of the NMA discussion includes "primer-like" information, the language herein should not be viewed as prescriptive. The analyst should not interpret this NMA as limiting flexibility in the conduct of the technical analyses or in the application of expert and engineering judgment. A broad range of tools, techniques, implicit or explicit analysis, and judgment may be required to address the diverse nature of wind hazards and effects as well as the potential for wind-induced correlated hazards and their effects.

Comprehensive documentation of the data and technical bases for the analyses and modeling decisions is a critical part of an HWPRA. Due to the limited number of recent HWPRAs, the advancement of understanding risks from HWs depends on detailed documentation to facilitate peer review of the HWPRA and to improve understanding of plant performance during and after the occurrence of HW events.

7-A.2 COMMENTARY TO HIGH WIND AT-POWER PRA TECHNICAL ELEMENTS AND REQUIREMENTS

7-A.2.1 Commentary to Wind Hazard Analysis (WHA)

For the purposes of this Standard, the HW hazard group includes the following wind-hazard types:

(a) straight winds (thunderstorm winds and extratropical cyclones)

(b) tropical cyclone winds (hurricanes and typhoons)

(c) tornadoes

The specific definitions and subgroupings of these HW hazard types are an integral part of the Part 7 scope, organization, and requirements. These distinct wind-hazard types have separate phenomenological characteristics, and observational data are typically contained in separate databases, the analysis of which requires different methods of analysis. The types of wind hazards identified in Wind Hazard Analysis are consistent with modern characterization of the phenomena and methods used for analysis for windstorms that have the capability to produce HW speeds. The analyst should be familiar with the sources of the data and the uses and limitations of these databases. There is significant literature regarding data sources and analysis methods for straight winds, tropical cyclones, and tornadoes.

Straight winds include thunderstorm winds and extratropical cyclones. HW speeds in thunderstorms are associated with gust fronts, derechos, and downbursts. Extratropical storms are often referred to as "winter storms," "midlatitude cyclones," or "Nor'easters" [in the eastern United States (US)]. These storms cover large areas, may have durations of hours to days, and may produce wind-driven storm surges for sites near large bodies of water.

Tropical cyclones have a low-pressure center and generally form over warm ocean water, predominately in the tropics. Tropical cyclones are often referred to as "hurricanes," "cyclones," or "typhoons," depending on location and storm intensity. Tropical cyclones cover large areas, and the duration of HWs at a site can last for hours. Tropical cyclones are often accompanied by intense rain and may produce wind-driven storm surge.

A tornado is defined as "a rotating column of air, in contact with the surface, pendant from a cumuliform cloud, and often visible as a funnel cloud and/or circulating debris/dust at the ground" (AMS, [7-A-10]). It is important to note that the tornado literature emphasizes that tornado reporting is not efficient in low-population areas, and many tornadoes may go unreported in areas where few people live. Tornadoes occur with a wide range of intensities, lengths, and widths and may have single or multiple vortices. Tornado intensities are estimated from observed damage; therefore, the intensity levels (F and EF scales; Fujita, [7-A-11] and Texas Tech University, [7-A-12]) must be converted to wind speeds in the tornado hazard analysis. Typically, there are significant uncertainties in estimating tornado hazard wind-speed frequencies.

It is important to note that various national wind-loading standards may refer to additional types or subtypes of wind hazards. For example, ASCE 7 [7-A-13] refers to "special wind regions," which include mountainous terrain, gorges, and other complex terrain regions identified in the ASCE 7 wind-speed maps. Sites in such areas may be subject to unusual wind conditions and may have high local wind speeds resulting from complex terrain and/or simple, isolated topographic speed-ups (of the type included in ASCE 7). In addition, sites in arid or semiarid locations may be subject to windstorms with significant amounts of entrained dust or sand. A separate hazard distinction for "special or unusual" wind conditions is not included in Part 7. There is a consensus that plants sited in such locations would be very unusual, so the Wind Hazard Analysis requirements for site and regional anemometer analysis under the straight wind hazards would be sufficient to identify any "special wind" conditions that may exist at a site. In this regard, it is noted that topographic speed-ups are included as an SR. Due to the highly site-specific nature of unusual wind environments and following ASCE 7 recommendations for such locations, consultation with a wind engineer or meteorologist is advised if the site is deemed to be subject to "special winds." These analyses may require expert consultants, review of historical storm documentation and records, modeling, and/or wind tunnel testing to develop the information necessary for the hazard and fragility analyses.

Wind Hazard Analysis uses wind speed as the HW independent hazard parameter, consistent with national and international codes and standards. Because wind pressure loads on rigid structures and components are proportional to the square of the wind speed, the use of wind speed as the independent wind-hazard parameter introduces an inherent sensitivity to uncertainties in the wind-speed frequencies. Wind-generated missile effects are generally proportional to a higher exponential power of wind speed due to the number of missiles produced and the higher missile speeds that result from an increase in wind speed. Flexible structures are also proportional to the wind speed at a higher exponential power. Small changes or uncertainties in wind speed for a given return period can result in significant changes in analyzed load effects and in the failure frequency of a vulnerable SSC. Therefore, the development of mean frequencies, considering aleatory and epistemic uncertainties, is a critical part of the Wind Hazard Analysis and is essential to producing accurate HWPRA results.

Site-specific wind hazard analysis generally requires the consideration of regional data. The size of the region requires judgment and depends on the regional climatology and type of wind hazard, the number of years for which accurate records are available, the extent and quality of the data, and the hazard's spatial variability within the region.

Care must be taken in understanding the sources and quality of the data in the site Wind Hazard Analyses. For example, a "site" anemometer may be poorly sited, may not include archived peak gust data, may not have continuous records, or may not have sufficiently long records. There are no ready fixes for data produced from poorly sited anemometers. Differences in anemometer types, siting history, and conditions can have notable impacts on the recorded wind speeds. The emphasis on data quality and analysis in Part 7 for Wind Hazard Analysis follows directly from widely recognized requirements in wind-hazard modeling. For example, ASCE 7-16 (Section 26.5.3) [7-A-3] includes a list of requirements regarding analysis procedures when wind hazard analysis is undertaken in lieu of the basic wind speeds provided in that standard. Understanding these and other limitations of wind-hazard data is essential to producing wind-hazard frequencies that are accurate and that represent the appropriate uncertainties.

Table 7-A.2.1-1 Commentary to High Level Requirement for Wind Hazard Analysis (WHA)

Designator	Commentary
HLR-WHA-A	No commentary provided.
HLR-WHA-B	No commentary provided.
HLR-WHA-C	No commentary provided.
HLR-WHA-D	No commentary provided.
HLR-WHA-E	No commentary provided.
HLR-WHA-F	No commentary provided.
HLR-WHA-G	No commentary provided.

Table 7-A.2.1-2 Commentary to Supporting Requirements for HLR-WHA-A

Index No. WHA-A	Commentary
WHA-A1	Examples of potentially relevant HW hazards include, but are not necessarily limited to *(a)* straight winds *(b)* tropical cyclone *(c)* tornado *(d)* wind-driven rain
WHA-A2	Examples of relevant information may include historical, regional, and site-specific HW data; HW characteristics; and HW vulnerabilities. Relevant wind hazard data and analyses can often be found in national standards (e.g., ASCE 7-16 [7-A-3] in the US), NUREGs, National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center (NCDC), and the literature. In addition, site information is available at many plants.
WHA-A3	Straight winds occur everywhere on earth. Extreme values of straight winds can exceed 125 mph, and downburst wind speeds of 150 mph have been documented. Consequently, deterministic screening is not allowed for straight winds, but they can be screened out using probabilistic screening. *Probabilistic Screening.* Probabilistic screening focuses on use of bounding/conservative hazard frequencies for screening but also considers the reliability of site protection and mitigation.

Table 7-A.2.1-2 Commentary to Supporting Requirements for HLR-WHA-A (Cont'd)

Index No. WHA-A	Commentary
WHA-A4	Two methods of screening for tropical cyclones are allowed in SR WHA-A4. *Distance Screening.* The use of 150 miles (approximately 250 km) as screening distance was developed based on a review of multiple plant locations in the southeast US, where recent HWPRAs have been performed with hurricane winds included. At about this distance, the hurricane HW frequency falls below 20% of the total HW frequency for wind-speed bins of interest. The contribution to CDF was found to be less than a few percentages. Therefore, at this distance and beyond, tropical cyclones are expected to make an insignificant contribution to the HW risks. *Probabilistic Screening.* Probabilistic screening focuses on use of bounding/conservative hazard frequencies and fragility analyses.
WHA-A5	Tornadoes may be screened from the HWPRA using exclusion screening or probabilistic screening. These concepts are similar to the approaches allowed for tropical cyclone screening. *Exclusion Screening.* Because tornadoes are not always reported and many countries may not have an official record for tornadoes, the analyst should be aware that the lack of reporting of tornadoes does not always mean that the hazard does not exist. For example, in regions that have severe thunderstorms, the meteorological conditions exist for tornadoes. Exclusion screening should therefore consider tornado reporting in nearby regions/countries with similar climatology, as well as the climatology of the region and the potential for tornadic conditions to be present. *Probabilistic Screening.* Probabilistic screening focuses on use of bounding/conservative hazard frequencies for screening but also considers the reliability of site protection and mitigation.
WHA-A6	This SR is intended to reflect the importance of ensuring that the aggregate risk from all HW hazards that are screened out is not significant when considering the baseline risks of the plant (e.g., ensure there is not a large number of HW hazards that "barely screen" out individually, such that their aggregate contribution may be important).
WHA-A7	A walkdown is required for performing probabilistic screening under SRs WHA-A3, WHA-A4, and WHA-A5. It is important to note that SSCs that are pertinent to HW events may not be identified in the internal-events PRA. For example, the walkdown should consider barriers, doors, off-site power lines, tanks, and other equipment uniquely related to the plant's HW response (e.g., Sciaudone et al., [7-A-14]; Lovelace et al., [7-A-15]). An example approach can be seen in the Electric Power Research Institute (EPRI, [7-A-16]) HW walkdown guidance document. SR WHA-A6 does not require that the screening walkdown meet the walkdown requirements of HLR-WFR-B. Therefore, for optional wind hazard screening, the PRA team should decide whether or not they are going to do a complete walkdown according to the SRs under WFR-B. For example, if a simplified walkdown is sufficient to support screening but the screening is not successful for all wind hazards, then the PRA team may need to conduct a supplemental walkdown to satisfy the WFR-B SRs. When determining the scope and details of the walkdown, it is important that the intent of the walkdown be considered. The intent is to identify items that invalidate modeling in the PRA to such an extent that the model does not reasonably represent the as-built, as-operated plant. In keeping with this intent, it is acceptable that conditions that can be justified as not likely to affect the results (i.e., will not change the risk profile or insights) do not need to be validated. As such, and per Inquiry 20-2435 [7-A-17], it is not required that 100% walkdown be performed if adequate justification can be provided that a lesser scope will suffice. There are various justifications that could be considered valid, but they must show *(a)* that items that could have a significant impact were walked down and *(b)* that those items not walked down could not have a significant impact. The following are examples of possible justifications: *(a) Bounding Risk Impact:* If the importance measure of an item is low, such that even if the item were assumed failed all the time, the PRA results would not meaningfully change. *(b) Adequacy of Documentation:* There is a sufficient weight of evidence, through drawings, photos/videos, analyses, or interviews with knowledgeable plant staff, that the conditions are as assumed in the PRA. *(c) Impact of Possible Discoveries:* Given past experience with the types of deviations typically found during walkdowns, it is not credible or likely that a deviation would be found that could affect the conditions assumed in the PRA to the extent required to meaningfully change the results.

Table 7-A.2.1-3 Commentary to Supporting Requirements for HLR-WHA-B

Index No. WHA-B	Commentary
WHA-B1	The analyst must define the reference wind parameters for each wind hazard in the HWPRA. Use of the same reference wind parameters for all wind hazards affecting a site simplifies the PRA and the fragility analysis. The parameters required to define the reference wind include *(a)* averaging time, *(b)* surface roughness, *(c)* height above ground, and *(d)* direction. For example, in ASCE 7-16 [7-A-3], the reference wind is specified as a 3-sec gust in open terrain at 10-m height above ground. The Canadian Code (NRCC, [7-A-18]) uses hourly wind speeds, whereas the Australian code (AS/NZS, [7-A-19]) uses a 0.2-sec peak gust, and the British Code (BSI, [7-A-20]), which references the European standard, is based on a 10-min average. It is important that the analyst understand the parameters of the standard reference wind speed in the country/region in which the site is located so that informed decisions are made regarding the PWHA reference wind parameters. The reference wind generally includes all possible wind directions; that is, the reference wind is not based on a particular wind direction. However, note that in several recent HWPRAs, directional wind analysis was used to support wind-generated missile analysis for straight winds and for wind-driven rain analysis. In these studies, the analysis of the wind data was performed to produce wind-speed frequencies by directional octant, and these directional frequencies were used in the analysis. The results in Banik et al. [7-A-21] show that considering wind direction for straight winds can be used to reduce fragility conservatisms in a detailed modeling approach of building fragilities. An important connection between Wind Hazard Analysis and Wind Fragility Analysis is the use of reference wind as the independent variable for both analyses. This approach, consistent with modern wind-fragility modeling methods (e.g., ASCE 7-16 [7-A-3], Vickery et al., [7-A-22]; Pinelli et al., [7-A-23]; Twisdale et al., [7-A-7]; and Konthesingha et al., [7-A-24]), requires consideration of the wind effects (e.g., loads) and associated structural resistances in the fragility analysis. Note that wind effects and wind-load considerations such as wind-field characteristics, wind-speed variation with height, site-surface roughness, wind directional variation, topographic speed-ups, shielding/negative-shielding effects, gust effects, and missile effects are appropriately included in the scope of the Wind Fragility Analysis and not in the Wind Hazard Analysis. This approach is consistent with national standards and standard wind-engineering practice.
WHA-B2	Wind data may not always correspond to the analyst-defined reference wind parameters. In this case, the analyst will need to convert the wind data to reference wind conditions as part of the Wind Hazard Analysis. It is important to understand the details of the historical wind records at a site or meteorology station. Standards have changed over time, and the averaging time, exposure, and height of the anemometer can introduce significant biases into the frequency analysis. The sample frequency and averaging times of the measured wind speed are obtained from the source providing the wind-speed data. For example, if the wind-speed measurements are not continuous in time (e.g., periodic, or hourly), the data likely do not contain the true daily or annual maxima, and it is likely that the wind hazard frequencies developed from such data will underestimate the true wind hazard frequencies. Vickery and Twisdale ([7-A-25]) provide an example of this situation by comparing results for a site anemometer with only hourly data to nearby airport station data, which includes peak gust wind speed measurements (also see the discussion under SR WHA-C1). All measured wind speeds need to be adjusted to a common averaging time. Gust factor curves such as those given in ASCE 7-16 [7-A-3] can be used to account for small averaging time differences. A useful reference for performing the adjustments for height, averaging times, and the effects of upstream terrain is Masters et al. [7-A-26].

Table 7-A.2.1-3 Commentary to Supporting Requirements for HLR-WHA-B (Cont'd)

Index No. WHA-B	Commentary
WHA-B3	For sites that are in regions where thunderstorms occur, the use of averaging times for straight wind that do not correspond to peak gusts can introduce significant underestimation errors in the Wind Hazard Analysis. In thunderstorm regions, if the available wind data do not include gust wind speeds, obtained from a continuous record, data sources that contain wind gust data from areas with similar climatology may need to be considered. The reason for considering other data sources is that averaging times longer than a few minutes will filter out the effect of thunderstorms and other short duration wind events. The use of data from similar regions that do record peak gust information would likely enable the development of appropriate gust factors for the site. For sites located in regions where thunderstorms are not a significant part of the HW climatology, the use of longer averaging times than peak gust is acceptable for the straight-wind analysis. In this case, peak gust factors derived from extratropical cyclones can be used to convert to peak gust winds, as needed. Tornado wind speeds are generally assumed to correspond to peak gusts since tornado intensities and associated wind speeds are based on observed damage.
WHA-B4	The HWPRA failure calculations begin with a specified minimum V_L wind speed. Wind speeds less than V_L are evaluated as not contributing significantly to SSC failure frequencies in the calculation of the plant's CDF and LERF. Plant challenges resulting from wind speeds lower than V_L are assumed to be part of weather patterns that are implicitly included in the internal events PRA. For example, the internal event PRA uses a LOOP frequency associated with weather phenomena at the plant and the electrical supply grid. The HWPRA is therefore concerned only with HWs $\geq V_L$ that strike the plant site. These winds may sometimes strike the grid away from the plant, but they must strike the plant to be considered within the scope of an HWPRA. HW events remote from the site are generally considered within the internal-events loss-of-off-site-power assessment and are included in the internal-events PRA model via the LOOP initiating-event frequency. Reviews of the plant's wind-damage experience and the SSC design bases are suggested as part of the determination of V_L. The V_L wind speed should be low enough to capture the lower tail of fragility functions of the most vulnerable high-wind target list (HWTL) SSCs but not so low as to include winds that are not risk significant to the most vulnerable SSCs on the HWTL. Similarly, if V_L is too high, then the HWPRA will ignore potentially important risk contributions from modest winds. For example, Kaasalainen et al. [7-A-27], Mironenko and Lovelace [7-A-1], and Kitlan and Mironenko [7-A-28] point out the dominant contributions of winds in the range of 73–157 mph to the CDF in recent HWPRAs. A number of recent HWPRAs used a V_L value of 73 mph, which corresponds to Fujita's original F1 wind-speed range (Fujita, [7-A-11]). Starting at 73 mph may result in the loss of some of the lower tail contribution to failure of weak structures, such as a transmission tower (see Twisdale et al., [7-A-29]) or cladding from a metal-clad structure, but a tradeoff is warranted in order to avoid having the dominant risk contribution be from random failures (vs. HW failures) in the lowest wind-speed interval used in the HWPRA calculations. In general, wind speeds lower than about 73 mph are assumed to be considered in the internal-events model. Many plants have experienced maximum winds within 60–70 mph, which is consistent with the number of plant-operating years and straight wind hazard analysis. Only a few plants have experienced winds over 80 mph. Typical design criteria for plant transmission lines and turbine building cladding often result in failure fragilities that are not insignificant for winds less than 100 mph (e.g., see Mironenko and Lovelace [7-A-1], Twisdale et al. [7-A-29], Lovelace et al. [7-A-9], Twisdale [7-A-30], Banik et al. [7-A-21]). The selection of V_L remains an area where coordination with internal-events PRAs is needed due to the potential sensitivity of the results to the selection of V_L.
WHA-B5	Wind hazard frequency curves are steep, typically characterized by a significant change in exceedance frequency for relatively small changes in wind speed. This characteristic influences the number and spacing of the wind-speed intervals needed for accurate calculation of failure frequencies in the HWPRA. Twisdale et al. [7-A-29] presents results on how the number of discrete wind-speed intervals in the computation of SSC failure frequencies impact the plants' computed CDF. This paper showed that using too few intervals, especially for low wind speeds, results in overestimation of the failure frequencies. The plant CDF was overestimated by about 35% when 5 vs. 10 intervals were used. The paper recommends at least 10 wind-speed intervals for reasonably accurate failure frequency calculations in HWPRAs. Kaasalainen et al. [7-A-27] similarly points out that the use of 10 vs. 5 calculation intervals reduced the plant HW CDF by 50%.

Table 7-A.2.1-3 Commentary to Supporting Requirements for HLR-WHA-B (Cont'd)

Index No. WHA-B	Commentary
WHA-B6	Recent HWPRAs (Kaasalainen et al. [7-A-27]; Mironenko and Lovelace, [7-A-1]; Kitlan and Mironenko, [7-A-28]) indicate that the major contributions to CDF and LERF frequently occur at wind speeds less than about 150 mph. Direct measurements of HW speeds are difficult due to their rare occurrences, relatively small areas affected by the highest winds, and sparse network of measurement systems, some of which are also vulnerable to failure in extreme winds. Notwithstanding the potential limitations of HW-speed measurements, the following references give some indication of high observations to date: 150 mph for downbursts (Fujita, [7-A-31]), about ≥ 200 mph for tropical cyclones (named Camille, Patricia, Allen, Wilma, etc.), about ≥ 200 mph for extratropical cyclones (Cerveny et al., [7-A-32]), and ≥ 300 mph for tornadoes with mobile Doppler radar (Wurman et al., [7-A-33]). These observations, coupled with the exponential relationship between Annual Exceedance Frequency (AEF) and wind speed, frequently make attempts to truncate or limit the wind speeds in the site wind hazard model unsuccessful, with little potential benefit in terms of impact on the computed CDF. Twisdale et al. [7-A-29] presents failure-frequency integration results for a range of 73–318 mph, with the last calculation interval covering a range of 260–318 mph. The last range was sufficient to capture the upper-tail fragility contributions for all but the strongest SSCs.

Table 7-A.2.1-4 Commentary to Supporting Requirements for HLR-WHA-C

Index No. WHA-C	Commentary
WHA-C1	Most wind engineers rely on the wind-speed data archived by the NCDC. The user of the data should find information on anemometer height, anemometer type, averaging times, and exposure (surrounding terrain) and account for the effects of these in the analysis of the wind-speed data. Data from multiple stations around the site are commonly used in straight wind frequency analysis (ASCE 7-16 [7-A-3]; Vickery and Twisdale, [7-A-25]). Multiple stations within the same regional climatology provide significantly more data to ensure confident estimation of rare wind speeds, help to ensure that anomalous or poor-quality data from any one station are not used in the analysis, and provide a spatial view of the regional straight-wind frequencies near the site. Twisdale et al. [7-A-34] notes that five to eight regional NOAA stations have been used for the site analysis in recent HWPRAs. Nuclear plants usually have a meteorological tower with archived wind data. The analyst must evaluate the siting history and exposure of the anemometer, continuity of records, and type of archived data to determine if they can be used for wind-speed frequency analysis. Vickery and Twisdale [7-A-25] present a wind hazard frequency analysis based on a plant's archived hourly data, noting that the plant did not have archived peak gust data. A comparison of the wind-speed frequencies from the site analysis (based on hourly data) with the surrounding NOAA stations shows a very significant underestimation of peak gust wind-speed AEFs. These differences were judged to be due to the effects of terrain at the plant and the use of hourly averages, which effectively removes thunderstorm gusts. In this case, the site data were rejected and not used in the HWPRA. For sites in complex terrain, the analysts should also check national wind standards and other publications to see if the site is in a "special wind" region. In ASCE 7, "special winds" refers to "regions in which wind speed anomalies are known to exist, such as winds blowing over mountain ranges, through gorges, or river valleys." As an example, the downslope winds near Boulder, Colorado, are a well-known special wind phenomenon (Durran, [7-A-35]). Wind speeds in these regions can be substantially higher than those indicated on the ASCE 7 wind-speed maps. In the US, wind maps in ASCE 7 can generally be used in the determination of special wind regions. In addition, knowledge of local meteorology conditions and historical storms may also be a part of assessing the potential for special winds at a site. Information from site anemometers, weather records, or other historical information may help determine whether special wind conditions are present.

Table 7-A.2.1-4 Commentary to Supporting Requirements for HLR-WHA-C (Cont'd)

Index No. WHA-C	Commentary
WHA-C2	Data used in the hazard analysis should be consistent in terms of the same averaging time, height, and open terrain conditions. Masters et al. [7-A-26] provides a reference for the adjustments for height, averaging times, and the effects of upstream terrain. Gust factor curves such as those given in ASCE 7-16 [7-A-3] can also be used to account for small averaging time differences. In addition, adjustments for height, terrain, and averaging time can be performed by using information given in the textbook by Simiu and Scanlan [7-A-36]. Also, Wieringa ([7-A-37]) and Beljaars [7-A-38] provide methods to adjust for terrain if information on the gust can be derived from the data. If gust data are not available, then the roughness of the local and upstream terrain can be estimated using aerial imagery and mapping of the land-use category to surface roughness using data published in the literature (e.g., Wieringa, [7-A-39]). The wind-speed data in ASCE 7-16 includes such corrections for all the stations considered in the wind-speed map development. Vickery and Twisdale [7-A-25] demonstrate the importance of understanding the details of the historical wind records at each meteorology station. As wind measurement instruments and standards change over time, the averaging time, exposure and height of the anemometer and type of anemometer may introduce important eras/biases into the wind-speed frequency analysis. The sample frequency and averaging times of the measured wind speed must be obtained from the source providing the wind-speed data. As noted in SR WHA-B2, if the wind-speed measurements are periodic, it is likely that the wind hazard frequencies developed from such data will underestimate the true HW hazard, as the data will not contain the true daily or annual maxima. For advanced analysis, Engineering Science Data Unit (ESDU) [7-A-40] provides a computer code for assessing the effects of upstream roughness on anemometer wind speeds. Other computer models are available that can be used to adjust for terrain. Judgment is usually required in the application of the terrain adjustment factors (e.g., ASCE 7-16). To the maximum extent practical, the analyst should ensure that computer programs employed in the analysis of wind data have the appropriate pedigree by virtue of being benchmarked against actual phenomena and that they possess adequate validation/verification.
WHA-C3	A CC-I straight-wind analysis provides for an extreme value analysis of anemometer station data without distinguishing the type of storm that produced the data. When storm types are not separated out, the resulting data are "mixed," and there will be data from large-scale systems, like extratropical storms, as well as data from severe local storms, like thunderstorms. Using mixed data to predict rare, HW-speed events can introduce considerable unknown bias errors and uncertainties in the resulting wind hazard frequencies (e.g., Holmes, [7-A-41]; Lombardo et al. [7-A-42]). Information is available in many countries to distinguish thunderstorm from nonthunderstorm straight winds, including but not limited to the US, Canada, Germany, South Africa, and Australia. The separation of thunderstorm and nonthunderstorm winds and their treatment as statistically independent events was first proposed by Gomes and Vickery [7-A-47] for developing wind hazards in Australia. After this use, the applicability of the method was widely accepted in the US. Twisdale and Vickery [7-A-48] also showed that thunderstorms dominated the extreme winds over most of the inland US. Recent publications include Letchford and Ghosalkar [7-A-49], Lombardo et al. [7-A-50], and Lombardo et al. [7-A-42]. Vickery and Twisdale [7-A-25] summarize the approach and present discussions and methods for uncertainty analysis. Holmes [7-A-41] illustrates how the separation of thunderstorm from "synoptic" winds and their recombination produces a combined straight-wind distribution that captures both the synoptic winds at less frequent return periods and the thunderstorm "downbursts" at more frequent return periods. A downburst is an area of strong, often damaging winds produced by one or more convective downdrafts (AMS, [7-A-10]). Downburst wind speeds of 150 mph have been measured at an airport and other estimates of straight-wind gusts up to 179 mph reported (e.g., Fujita, [7-A-31], NOAA, [7-A-51]).

Table 7-A.2.1-4 Commentary to Supporting Requirements for HLR-WHA-C (Cont'd)

Index No. WHA-C	Commentary
WHA-C3 (Cont'd)	A significant problem associated with CC-I can occur when annual extremes for a few decades of data are used to produce wind-speed risk for return periods > 100 yr. Since straight winds often dominate a site's wind hazard frequencies out to ≥ 1,000-yr return periods, the use of mixed data can introduce considerable errors and uncertainties. These problems can be reduced with the use of multiple stations of data, including the use of a superstation approach, as was done for ASCE 7-98 [7-A-43] by Peterka and Shahid, [7-A-44]). Other methods include the method of independent storms (Cook, [7-A-45]) and the peaks over threshold method (Davison and Smith, [7-A-46]). If the site is in a hurricane-prone region, extremes from tropical cyclone storms should be removed from the mixed straight-wind data set prior to analysis. The separation methodology is the basis for the straight-wind analysis used in the wind-speed maps in ASCE 7-16 [7-A-3], noting that the ASCE maps also include hurricane winds near the coast. Straight-wind-speed maps based on separation of thunderstorm and nonthunderstorm winds (without hurricanes) are given in map form in NIST Special Publication 500-303 [7-A-52]. The benefits of a separate analysis are more accurate estimation of extreme straight winds and reduced uncertainties resulting from having larger data sets. For example, if a station has 30 yrs of reliable data and there is an average of 15 thunderstorms a year, a total of 450 wind-speed events can be used in the analysis for a single station, whereas an annual extreme value analysis would have only 30 wind speeds (of mixed events). The use of coherent (not mixed) data sets with many more events provides much more confidence for the important wind-speed AEFs < 1.0E-02. The states of the art and practice for combining different wind hazard-type (e.g., thunderstorms and extratropical cyclone) frequencies on a per-year time interval are to assume statistical independence (e.g., Simiu and Scanlan, [7-A-36]; Vickery and Twisdale, [7-A-25]).
WHA-C4	As a point of reference, a commonly used wind-speed distribution for straight-wind analysis is the Gumbel or Extreme Value Type I Distribution. For example, ASCE 7-16 [7-A-3] has used Type I for all editions in the modern era of the Standard. Some researchers have investigated "tail-limited" distributions (e.g., Simiu and Heckert, [7-A-53]). Tail-limited distributions are strongly influenced by a few wind speeds in the tail. A major concern with tail-limited distributions in an HW risk assessment is the capping of wind speeds based on a limited data set that may not include rare but intense downburst winds that may dominate straight-wind AEFs < 1E-02. That is, a 20- or 30-yr data set is unlikely to include rare, small-scale straight-wind phenomena associated with, for example, 100-, 500-, 1,000-, and ≥ 5,000-yr return periods. The concern is that wind speeds for this range of return periods cannot be accurately estimated by tail-limited distributions based on data samples that do not include such phenomena. The use of tail-limited distributions has been questioned by, for example, Cook and Harris, [7-A-54]; Harris, [7-A-55]). Thus, if the analyst uses a tail-limited distribution, it is recommended that a supporting basis be developed and documentation provided to support a technical peer review.
WHA-C5	In the analysis of straight winds, multiple stations are often used due to the limitations of short-term data records for any one station. For a nuclear plant site, the analyst must often determine how to combine the regional data/analyses to produce the site-specific straight-wind risk. For example, the analyst might make the case for equal weights in a homogeneous region or might conclude that weights should be based on the inverse of distance from the plant. A superstation approach could also be considered, as was used by Peterka and Shahid [7-A-44] in ASCE 7-98 [7-A-43]. ASCE 7-16 [7-A-3] used a smoothing approach from many individual stations in the updated wind-speed maps. Due to the aforementioned issues on data quality, data corrections, limitations of short-term records, and large uncertainties, the use of a single station's records for a site's straight-wind model should be avoided when lacking state-of-the-practice regional analyses/comparisons to provide adequate justification.

Table 7-A.2.1-4 Commentary to Supporting Requirements for HLR-WHA-C (Cont'd)

Index No. WHA-C	Commentary
WHA-C6	Comparison of the straight-wind hazard frequencies developed for the Wind Hazard Analysis to data specified in national wind-loading standards (or to relevant data published in the literature following publication of the national standard) provides useful perspectives for both the analyst and the peer reviewers. Wind hazard curves used in wind-loading standards (and most of those that appear in the literature) do not include the effects of propagating epistemic uncertainties. In general, due to the nonlinear nature of error propagation, the inclusion of epistemic uncertainties produces higher mean hazard frequencies (NUREG/CR-6372 [7-A-55]; Vickery and Twisdale, [7-A-25]; Twisdale et al., [7-A-29]). As discussed in [7-A-25], aleatory parametric uncertainties typically include the statistical parameters of the extreme value distribution. Epistemic uncertainties may include, among others, corrections for anemometer height, which is based on surface roughness; corrections for surrounding terrain; and corrections for averaging time based on measurement systems used in the data record period. Vickery and Twisdale [7-A-25] demonstrate how the combination of regional extremes in a site analysis result in uncertainty curves that contain rare extreme straight-wind speeds, whereas, by comparison, the same data appear as outliers to single-site fifth and 95th uncertainty curves.

Table 7-A.2.1-5 Commentary to Supporting Requirements for HLR-WHA-D

Index No. WHA-D	Commentary
WHA-D1	In recent HWPRAs, two methods have been applied for the tropical cyclone wind-speed frequency analysis: *(a) Existing Study.* Examples of tropical cyclone publications that provide sufficient information to derive a hazard curve include Vickery et al. [7-A-57], coupled with NUREG/CR-7005 [7-A-4], ASCE 7-10 [7-A-13], or ASCE 7-16 [7-A-3]. It is important to note that the latter two examples contain both tropical cyclone and non-tropical cyclone data combined as statistically independent processes. *(b) Model Calculations.* Tropical cyclone wind hazard curves cannot be developed by using historical wind-speed data. A tropical cyclone simulation model is the preferred method for developing the wind-speed frequencies. For use in an HW PWHA, the model should have been published and should represent the current state of the art. Each model component should be individually validated. Such model components include, but are not limited to, the wind field model; statistical models for storm size, central pressure, frequency, landfall location, translation speed, heading, and Parameter B, described by Holland [7-A-58]; or other parameters that control the relationship between central pressure and wind speed. Examples of model validation are given in Vickery et al. ([7-A-59], [7-A-60]) and James and Mason [7-A-61]. A discussion of hurricane hazard modeling is also contained in Vickery et al. [7-A-57].
WHA-D2	The data sources listed in SR WHA-D1 commentary provide several sources that can be used to compare results from model calculations performed under SR WHA-D1. There are aleatory and epistemic uncertainties in each component of a tropical cyclone model. For the model calculation approach, the uncertainties in the data and in each submodel should be propagated through the hazard model. Regarding data sources, it is important to note that the period of record of quality tropical cyclone data varies from basin to basin and with the type of data. For example, along the US coastline, there is an almost complete set of landfall central pressure, heading, translation speed, landfall location, and frequency data extending back to about 1900, whereas quality data pertaining to storm size are limited to the 1940s and later. Maximum wind speeds given in the historical databases are estimated values rather than measurements.

Table 7-A.2.1 6 Commentary to Supporting Requirements for HLR- WHA-E

Index No. WHA-E	Commentary
WHA-E1	This commentary highlights a few key points in tornado hazard analysis and indicates that the state of the practice continues to improve at the time of this Standard. The tornado is a unique wind hazard containing the highest wind speeds in nature, varying widely in size and intensity, and requiring specialized databases that use damage observations for estimation of intensity. These characteristics make for a complicated analysis in order to produce tornado wind-speed frequencies that include aleatory and epistemic uncertainties. There has also been a burgeoning amount of new information and data over the past decade, and that trend is expected to continue. The following commentary attempts to highlight some of these recent developments, which suggest potential underestimation of tornado wind-speed risk in existing hazard standards, such as ANSI/ANS-2.3-2011 (R2021) [7-A-62], NUREG/CR-4461 [7-A-63], and FEMA [7-A-64]. Consequently, until updated maps are produced, a tornado analysis may require analysis that extends beyond readily available resources. Recent publications reinforce long-recognized tornado data issues and indicate a number of concerns in tornado risk estimation that were not considered in the above-referenced national tornado map products, including underestimation of risk due to unreported events in the modern era (Elsner et al., [7-A-65]; Skow and Cogil, [7-A-66]), low-biased wind speeds in the EF scale (Twisdale, [7-A-67]), potential underestimated EF ratings vs. Doppler radar measurements (Wurman and Kosiba, [7-A-68]), path-length intensity variation data (Faletra et al., [7-A-69]), uncertainties in damage-based tornado ratings (Edwards et al., [7-A-70]), and significant biases/errors in the evolution of the US national tornado databases (Verbout et al., [7-A-71]; Faletra et al., [7-A-73]). The resources mentioned above, and many others provide insights for model-based calculations of tornado hazard risk. With regard to new research and information sources, it is important to note that significant efforts are underway to develop ASCE standards for tornado wind-speed estimation (LaDue, [7-A-72]), tornado hazard maps (Phan et al., [7-A-5]), and tornado design standards for structural design (NIST SCSTAR 3, [7-A-74]). These efforts are expected to improve considerably on the current vintage of tornado wind-speed risk maps and provide a significant new resource for HWPRAs.
WHA-E2	As discussed in SR WHA-E1, there is significant and growing literature on tornado hazard modeling regarding the technical requirements in SR WHA-E2. The references listed under SR WHA-E1 provide a good primer for reviewing the important issues and variables influencing the analysis of tornado wind frequencies. A major consideration is that the EF-scale wind speeds may underrepresent tornado winds and are undergoing critical analysis for use in ASCE tornado wind-speed map estimation (LaDue, [7-A-73]). With the many data limitations and assumptions required in tornado hazard analysis, epistemic uncertainties are an important part of tornado hazard modeling and analysis.
WHA-E3	No commentary provided.
WHA-E4	The effects of target size in tornado hazard analysis have been documented in the literature since the 1970s (e.g., Garson et al., [7-A-75]; Wen and Chu, [7-A-76]; and Twisdale et al., [7-A-77]). As the target size becomes larger (e.g., a tornado striking any SSC at a nuclear plant), the chance of a tornado striking the target increase. This well-established effect creates a unique linkage between the tornado hazard curve development and its use in the fragility analysis. Twisdale et al. [7-A-7] illustrates typical tornado hazard curves for a point target (e.g., small building) and an example nuclear plant target used in wind-generated missile analysis. The ratios between these curves typically range from about 2 to 3 at low wind speeds to factors of 10 or more at HW speeds.
WHA-E5	Due to the aforementioned complexities of the tornado databases and wind-speed estimation, the analyst should carefully evaluate the potential limitations of past standards with respect to publications in any tornado hazard comparisons.

Table 7-A.2.1-7 Commentary to Supporting Requirements for HLR- WHA-F

Index No. WHA-F	Commentary
WHA-F1	Examples of aleatory and epistemic uncertainties and references are given in the discussion for the respective wind hazards.
WHA-F2	Examples of fractile and mean hazard curves for tornados are provided in Twisdale et al. [7-A-7] and Twisdale [7-A-67]. Examples of the fifth, 95th, and derived mean for straight winds and hurricanes are given in Vickery and Twisdale [7-A-25].
WHA-F3	No commentary provided.

Table 7-A.2.1-8 Commentary to Supporting Requirements for HLR- WHA-G

Index No. WHA-G	Commentary
WHA-G1	No commentary provided.
WHA-G2	No commentary provided.

7-A.2.2 COMMENTARY TO WIND FRAGILITY ANALYSIS (WFR)

The Wind Fragility Analysis requires a systematic evaluation of the effects of wind on SSCs. The independent fragility variable is the reference wind speed defined in the Wind Hazard Analysis. If the reference wind-speed parameters are different for different wind hazard types, the fragility analysis must also represent this distinction.

The Wind Fragility Analysis identifies four wind effects: *(a)* wind pressure and APC, *(b)* wind-generated missiles, *(c)* structural interactions, and *(d)* wind-driven rain. Wind pressure and APC effects are two separate effects that have been combined for purposes of this Standard, as both may affect the net pressure loads on an SSC. An analyst may choose to develop separate fragilities for wind pressure and APC effects and indicate how they are combined. Wind-driven rain includes the effects of rain that may accompany HW events. HW events can produce failure of building envelopes (wall cladding, roof cover/deck, and openings) that provide pathways for rain to enter the structure and that may result in failure of electrical equipment vulnerable to vertical and horizontal rain and associated drips and sprays. "Wind-driven rain" in Part 7 does not include local flooding from an HW event. If the rain in an HW event can produce local internal or external flooding, that effect is considered a correlated hazard.

Wind fragilities may be hazard dependent. Hazard dependence means that the fragility is dependent on the characteristics of the particular HW hazard type; that is, the SSC's fragility values for different wind hazards may not be the same for each wind-speed value. For example, recent work suggests that wind-generated missile fragilities may be different for tropical cyclones (hurricanes) than for tornadoes of the same or similar wind speeds (NUREG/CR-7004, [7-A-78]; Twisdale, [7-A-67]). The analyst must assess the potential for fragilities being dependent on the wind hazard type and develop fragilities accordingly.

Wind Fragility Analysis methods follow the national standards, where appropriate, and use much of the same terminology. New work in HWPRA fragility analysis has been completed in the past few years, and this information is referenced where appropriate.

The analyst should not interpret the commentary on Wind Fragility Analysis as limiting flexibility in the conduct of the technical analyses or in the application of expert and engineering judgment. A broad range of methods and judgment is required to analyze wind effects and develop fragilities for the dominant failure modes.

Table 7-A.2.2-1 Commentary to High Level Requirements for Wind Fragility Analysis (WFR)

Designator	Commentary
HLR-WFR-A	No commentary provided.
HLR-WFR-B	No commentary provided.
HLR-WFR-C	No commentary provided.
HLR-WFR-D	No commentary provided.
HLR-WFR-E	No commentary provided.
HLR-WFR-F	No commentary provided.
HLR-WFR-G	No commentary provided.
HLR-WFR-H	No commentary provided.
HLR-WFR-I	No commentary provided.

Table 7-A.2.2-2 Commentary to Supporting Requirements for HLR-WFR-A

Index No. WFR-A	Commentary
WFR-A1	No commentary provided.
WFR-A2	No commentary provided.
WFR-A3	No commentary provided.
WFR-A4	SSCs can fail under different wind effects. A wind effect, such as wind pressure or APC, can result in multiple failure modes, such as overturning, shear, bending, tension, uplift, and so on. The analyst should identify the dominant effects and failures modes for each SSC, considering the potential for both simultaneous-in-time effects and separated-in-time effects. Wind pressure loading effects are often considered with respect to the main wind force resisting system and components and cladding, see ASCE 7-16 [7-A-3]. Missile impact effects are often considered with respect to local effects (e.g., penetration, perforation, spall) and overall effects (crimping, bending, shear, and other structural or support failures). A common way to communicate these considerations is through a master list table that enumerates all failure modes for each SSC.
WFR-A5	Wind Fragility Analysis is complicated by the presence of multiple wind effects and the potential for multiple failure modes for each wind effect. In general, aggregations of effects and failure modes are essential in a PWFA. A systematic mapping of the wind effects, potential failure modes, and structural interaction to each SSC provides a reasonable approach to help organize the analysis, the aggregation, and the rationale. For wind pressure fragilities, a code-based approach (Kennedy and Ravindra, [7-A-79]; Twisdale, [7-A-30]) can be used to simplify the assessment of failure modes for complex structures by using load and resistance factors. As discussed by Lovelace et al. [7-A-9], area/volumetric modeling can be an effective method to handle the complexities associated with numerous equipment items within an area or room. This approach is similar to the “rule of the box” approach in seismic studies (Lovelace et al., [7-A-15]).

Table 7-A.2.2-2 Commentary to Supporting Requirements for HLR-WFR-A (Cont'd)

Index No. WFR-A	Commentary
WFR-A6	Using the same fragilities for different wind hazards depends on the similarities, or lack thereof, of the characteristics of the wind hazard. Tornadic winds are generally viewed as significantly different from nontornadic winds. For example, tornado winds include a vertical wind component and APC load effects. The rotational wind component in a tornado is often on a scale that is similar to the building length or width dimension, producing HWs from multiple directions in the same event. The tornado wind-generated missile risk has different characteristics than straight or hurricane wind missiles. Therefore, recent HWPRAs have evolved to use separate fragilities for tornadic and nontornadic winds (Twisdale, [7-A-67]). An important simplification for nontornadic fragilities results from similarities in gust factors and velocity profiles. For example, Vickery et al. [7-A-22] showed that the gust factors and velocity profiles in hurricanes can be treated with the standard factors used for extratropical storms, which provide the current basis for the pressure loads in ASCE 7-16 [7-A-3]. While there are important differences in thunderstorm wind characteristics (Twisdale and Vickery, [7-A-48]), there are insufficient data on which to develop separate thunderstorm wind load effects to warrant separate fragilities for these short-duration hazards. Recent HWPRAs have simplified the calculations to *(a)* tornadic fragilities specifically for the tornado hazard *(b)* nontornadic fragilities for straight winds and hurricanes Regarding wind-driven rain fragilities, several recent HWPRAs have shown that the rain probability and intensity are hazard dependent; for example, there is a much higher risk of intense rain during tropical cyclone events than during thunderstorms or tornadoes.
WFR-A7	The goal of this SR is to identify and evaluate potentially significant correlations for wind effects and failure modes. This requirement is listed under HLR-WFR-A to avoid repetition under each wind-effect SR in HLR-WFR-D, HLR-WFR-E, HLR-WFR-F, and HLR-WFR-G. The potential wind-effect and failure-mode correlations are large in number, are difficult to judge, and could require complicated 3-D physical models to estimate accurately. The degree of correlation is likely to be dependent on the wind-speed interval. The degree of failure-mode correlation at low wind speeds will likely be different from the correlation at HW speeds. Correlation of failures across SCCs within the same wind event and wind-speed interval may also vary significantly from one SSC to another. SSCs that are separated physically, that are not in the same structure, and that have opposite wind-direction vulnerabilities may have negatively correlated failures. Structural interactions from failures of a building frame, tower, and so forth may produce positive correlations across SSCs within or near these structures. A piping system could fail by missile perforation or crimping of the pipe, and these failure modes may be independent or positively or negatively correlated, based on the wind-speed interval. A discussion of wind-fragility correlations and the development of simple correlation bounds following structural reliability concepts are given in Twisdale, Lovelace, and Slep [7-A-29]. It is important to note that the simple bounds in this paper are based on percentage differences (and not ratios) with respect to a baseline assumption of statistical independence. Tighter bounds on SSC failure-mode correlation can be obtained through more detailed approaches (e.g., see Ditlevsen, [7-A-80]).
WFR-A7	In summary, due to *(a)* the complexity of wind-fragility correlation analysis; *(b)* the lack of published research/data in this area; and *(c)* the potential for large numbers of impacted SSCs in an HWPRA, engineering judgment coupled with the use of bounding correlation assumptions and sensitivity analyses may be useful for evaluating important fragility-related correlations. In recent HWPRAs, SSCs that are in close proximity or exposed to structural interactions have been viewed as important correlations that require consideration. For example, extremely close SSCs may be vulnerable to damage from a single large missile through simultaneous impact or missile ricochet.
WFR-A8	For wind-induced coexistent hazards, such as storm surge, it is important to address the impacts. ADDRESS does not imply the need for quantitative analyses.

Table 7-A.2.2-3 Commentary to Supporting Requirements for HLR-WFR-B

Index No. WFR-B	Commentary
WFR-B1	See Sciaudone et al. [7-A-14] and Lovelace et al. [7-A-15] for walkdown insights and guidance for HWPRAs. Also see EPRI [7-A-16] for additional guidance and as a comprehensive general resource [including example photographs from HW walkdowns conducted at operating nuclear power plants (NPPs)] for conducting HW walkdowns. When determining the scope and details of the walkdown, it is important that the intent of the walkdown be considered. The intent is to identify items that invalidate modeling in the PRA to such an extent that the model does not reasonably represent the as-built, as-operated plant. In keeping with this intent, it is acceptable that conditions that can be justified as not likely to affect the results (i.e., will not change the risk profile or insights) do not need to be validated. As such, and per Inquiry 20-2435 [7-A-17], it is not required that 100% walkdown be performed if adequate justification can be provided that a lesser scope will suffice. Various justifications could be considered valid, but they must show that *(a)* items that could have a significant impact were walked down and *(b)* those items not walked down could not have a significant impact. The following are examples of possible justifications: *(a) Bounding Risk Impact.* If the importance measure of an item is low, such that even if the item were assumed failed all the time, the PRA results would not meaningfully change. *(b) Adequacy of Documentation.* There is a sufficient weight of evidence, through drawings, photos/ videos, analyses, or interviews with knowledgeable plant staff, that the conditions are as assumed in the PRA. *(c) Impact of Possible Discoveries.* Given past experience with the types of deviations typically found during walkdowns, it is not credible or likely that a deviation would be found that could affect the conditions assumed in the PRA to the extent required to meaningfully change the results.
WFR-B2	See Sciaudone et al. [7-A-14] and Lovelace et al. [7-A-15] for walkdown insights and guidance for HWPRAs. Also see EPRI [7-A-16] for additional guidance and as a comprehensive general resource (including example photographs from HW walkdowns conducted at operating NPPs) for conducting HW walkdowns. When determining the scope and details of the walkdown, it is important that the intent of the walkdown be considered. The intent is to identify items that invalidate modeling in the PRA to such an extent that the model does not reasonably represent the as-built, as-operated plant. In keeping with this intent, it is acceptable that conditions that can be justified as not likely to affect the results (i.e., will not change the risk profile or insights) do not need to be validated. As such, and per Inquiry 20-2435 [7-A-17], it is not required that 100% walkdown be performed if adequate justification can be provided that a lesser scope will suffice. Various justifications could be considered valid, but they must show that *(a)* items that could have a significant impact were walked down and *(b)* those items not walked down could not have a significant impact. The following are examples of possible justifications: *(a) Bounding Risk Impact:* If the importance measure of an item is low, such that even if the item were assumed failed all the time, the PRA results would not meaningfully change. *(b) Adequacy of Documentation:* There is a sufficient weight of evidence, through drawings, photos/ videos, analyses, or interviews with knowledgeable plant staff, that the conditions are as assumed in the PRA. *(c) Impact of Possible Discoveries:* Given past experience with the types of deviations typically found during walkdowns, it is not credible or likely that a deviation would be found that could affect the conditions assumed in the PRA to the extent required to meaningfully change the results.
WFR-B3	When determining the scope and details of the walkdown, it is important that the intent of the walkdown be considered. The intent is to identify items that invalidate modeling in the PRA to such an extent that the model does not reasonably represent the as-built, as-operated plant. In keeping with this intent, it is acceptable that conditions that can be justified as not likely to affect the results (i.e., will not change the risk profile or insights) do not need to be validated. As such, and per Inquiry 20-2435 [7-A-17], it is not required that 100% walkdown be performed if adequate justification can be provided that a lesser scope will suffice. Various justifications could be considered valid, but they must show that *(a)* items that could have a significant impact were walked down and *(b)* those items not walked down could not have a significant impact. The following are examples of possible justifications:

Table 7-A.2.2-3 Commentary to Supporting Requirements for HLR-WFR-B (Cont'd)

Index No. WFR-B	Commentary
WFR-B3 (Cont'd)	*(a) Bounding Risk Impact:* If the importance measure of an item is low, such that even if the item were assumed failed all the time, the PRA results would not meaningfully change. *(b) Adequacy of Documentation:* There is a sufficient weight of evidence, through drawings, photos/videos, analyses, or interviews with knowledgeable plant staff, that the conditions are as assumed in the PRA. *(c) Impact of Possible Discoveries:* Given past experience with the types of deviations typically found during walkdowns, it is not credible or likely that a deviation would be found that could affect the conditions assumed in the PRA to the extent required to meaningfully change the results.
WFR-B4	See Lovelace et al. [7-A-15], Sciaudone et al. [7-A-14], and EPRI ([7-A-81], [7-A-82]) for missile-source modeling discussions and missile walkdown guidance. It is important to note that wind-generated missiles from failed structures are a major source of missiles in HWPRAs. Cladding and roof-deck failures are important sources of missiles. Roof ballast, such as concrete pavers, and gravel may be significant because these potential missiles can start at high elevation, such as the roof and walls of a turbine building. Twisdale [7-A-67] noted that the number of missiles developed through recent plant surveys included > 150,000, of which > 50% were from failed building sources. Metal cladding missiles have been identified as a major source of risk at several plants.
WFR-B5	No commentary provided.
WFR-B6	The plant operating conditions at the time of the missile survey are important. Outages generally result in a significant number of additional missile sources, including trailers, close to many SSCs (Sciaudone et al. [7-A-14]). A modeling approach to account for plant operating conditions is illustrated by Twisdale [7-A-67]. The build-up of materials prior to the outage, the outage duration, and the postoutage cleanup can amount to a notable fraction of time from one outage to another, particularly for multiple-unit plants.

Table 7-A.2.2-4 Commentary to Supporting Requirements for HLR-WFR-C

Index No. WFR-C	Commentary
WFR-C1	Screening for wind pressure effects could include, for example, seismic Category I structures that were designed for 360-mph tornado winds and APC effects. The justification could be based on a code-based analysis with load and resistance factors. Another example of wind pressure screening is a simplified overturning analysis of a tank or large piece of detached external equipment. The analyst might use bounding, conservative assumptions on overturning load, and weight to estimate a conservative, overturning wind speed. This type of screening would eliminate the need for more detailed fragility modeling for overturning failures. As part of the screening process, it is important to evaluate doors, vents, and other components for their design basis and/or whether failure of these components would affect interior, safety-related SSCs. An HW plant-design basis may not always suffice for screening. For example, a concrete roof slab of a seismic Category I structure may be only 8 in. thick and vulnerable to missile-induced spall or perforation. EPRI NP-2005 [7-A-82] includes information on missile perforation and spall of reinforced concrete that may be useful for screening. In addition, a plant's missile design basis may be insufficient for screening for missile effects. For example, a plant may have a wood beam and an automobile missile as the "design basis" missiles, with the automobile missile trajectory height limited to 30 ft. Such missile design bases do not eliminate risk from the steel cladding, purlins, girts, pipes, and other structural objects that may become missiles at a plant and impact SSCs at all elevations. HW screening of SSCs results in assigning a fragility of 0 to those SSCs not susceptible to HWs. The SSC, such as a pump or motor, can still fail from random failures; therefore, it should not necessarily be excluded from the HWPRA, even if it is screened out from HW failures.

Table 7-A.2.2-4 Commentary to Supporting Requirements for HLR-WFR-C (Cont'd)

Index No. WFR-C	Commentary
WFR-C2	SSCs that are screened out for missiles should not have significant risk vulnerabilities from missiles passing through doors, louvers, vents, or other openings. There is little guidance to determine significant missile risk vulnerabilities. "Line of sight" from the opening to the SSC is an approach that has been used within the industry. However, plant walkdowns have also uncovered situations where there may not have been a line-of-sight vulnerability but where a missile ricocheting from a nearby concrete surface was redirected toward and into the SSC (e.g., Sciaudone et al. [7-A-14]; Twisdale et al. [7-A-29]; Twisdale [7-A-67]). Also, if a wind-generated missile enters a building at a high elevation and then falls through the building, ricocheting along the way, a horizontal line-of-sight assessment would not be an acceptable screening approach.
WFR-C3	No commentary provided.
WFR-C4	SSCs that are qualified for outdoor environments and associated rain deposition and wind-driven rain should qualify for screening out.

Table 7-A.2.2-5 Commentary to Supporting Requirements for HLR-WFR-D

Index No. WFR-D	Commentary
WFR-D1	In the US, ASCE 7-16 [7-A-3] is an acceptable national wind standard for wind pressure loading for nontornadic winds. In modeling wind pressure load effects, an important consideration is the role of internal pressures, which are considered with respect to an open, enclosed, or partially enclosed building (ASCE 7-16). In wind storms, buildings may fail progressively (cladding, doors vents, roof elements, etc.), and the enclosure state may change from enclosed to partially enclosed to open. The enclosure state affects the internal pressures and net loads on the building. The role of progressive failure is well documented in the literature (e.g., NOAA, [7-A-83]; Vickery et al. [7-A-22]; Twisdale [7-A-30]; and Banik et al. [7-A-21]).
WFR-D2	Tornadoes are capable of producing significant APC loads (e.g., Simiu and Scanlon, [7-A-36]; Roueche [7-A-84]). The effects of APC loads are related to the background building leakage, envelope failures, the size of the tornado radius of maximum winds relative to the building, horizontal wind speed, translational speed, and other factors. Due to the limitations of the state of the art in modeling APC, simplified approaches with considerations of epistemic uncertainties may be appropriate.
WFR-D3	In the code-based approach (Kennedy and Ravindra, [7-A-79]) that is often used for wind pressure fragility analysis, factors are developed based on load and resistance information. Twisdale et al. [7-A-7] and Twisdale [7-A-30] discuss an enhanced code-based approach for wind pressure fragility analysis for structures and building envelopes. Regarding the use of a code-based approach, it is important to note that the loads and resistances referenced in earlier code eras may be significantly different from those employed today. For example, if a building was designed in the 1960s or 1970s, the pressure coefficients and reference wind are not the same as those used in modern code. The analyst should identify and correct for the important differences in the fragility analysis. Again, in the past, certain standards used fastest-mile wind speeds. Other standards simply allowed for a one-third stress increase to account for wind loads; this increase is no longer permitted. Pressure coefficients on components and cladding have increased in recent codes, representing improved wind tunnel data. These code differences can be important in an analysis of wind pressure fragilities for SSCs built prior to the most recent editions of the national building loading standard code.
WFR-D4	The analyst must determine if an SSC is a rigid or flexible (e.g., a chimney or tall building) structure. If the structure is flexible, the dynamic response characteristics should be included in the fragility analysis. For reference, ASCE 7-10 [7-A-13] defines a rigid structure as one with a fundamental frequency ≥ 1 Hz.
WFR-D5	A procedure for topographically induced wind speed-up effects is provided in ASCE 7-10 [7-A-13], including background references. It is important to note that Section 26.8 in ASCE 7-16 [7-A-3] does not address the general case of "wind flow over a hilly or complex terrain for which engineering experience, expert advice, or wind tunnel procedure may be required."

Table 7-A.2.2-5 Commentary to Supporting Requirements for HLR-WFR-D (Cont'd)

Index No. WFR-D	Commentary
WFR-D6	Code pressure coefficients in standards such as ASCE 7-10 [7-A-13] are based on isolated building wind tunnel tests. The effects that groups of buildings can produce on each other result in "shielding or negative shielding" effects on an individual structure. Shielding and negative shielding are also referred to as "sheltering" and "negative sheltering" (Cook [7-A-85]) and as shielding and "channeling." Others, such as Ho et al. [7-A-86], refer to these same effects as "variability of wind loads due to obstructions of surrounding buildings." Shielding effects are well recognized in wind engineering and provide the rationale for wind tunnel testing of tall buildings and bridges throughout the world. As implied, the effects of shielding and negative shielding can either reduce or increase the loads on a structure. Based on wind direction, it is possible to increase the loads without a clear channeling setup of the surrounding buildings. This SR directs that the analyst assess the potential for shielding and negative shielding in the wind pressure fragility analysis. One possible way to do it is through the use of statistical factors based on wind tunnel tests that introduce variability in the loads (Ho et al., [7-A-86]). The data can allow for a statistical treatment of both shielding and negative shielding (channeling of winds between obstructions that can produce speed-ups). In summary, the nature of nuclear plant sites, typically with groups of buildings located near the center of the site, will likely result in shielding and negative shielding effects. Without a wind tunnel test, the state of the practice is to apply factors/engineering judgment to account for these effects.

Table 7-A.2.2-6 Commentary to Supporting Requirements for HLR-WFR-E

Index No. WFR-E	Commentary
WFR-E1	It is important that site-specific hazard models and data be used in the development of wind-generated missile fragilities. It should be noted that site-specific information may need to utilize representative nearby information to justify the site-specific hazard models. Missile fragilities are based on missile impact and damage assessments. Missile fragilities therefore include the probability of one or more missiles impacting the SSC as well as the probability of damage to the SSC. Both missile-impact probability and damage given an impact are dependent on the missile type. Lightweight missiles may have a much higher impact probability than heavy missiles. However, lightweight missiles may not be able to damage certain rugged SSCs. Thus, it is important to develop missile fragilities in a manner that recognizes the missile-type dependence in the fragility analysis of the SSC. Important hazard characteristics include the velocity profile of the horizontal winds, storm width, storm direction, rotational velocity components, radius of maximum winds, and vertical winds. These hazard characteristics are different for tornadic and nontornadic wind hazards. Recent HWPRAs have analyzed missile risk for two major classes of wind hazard: tornadic and nontornadic (Twisdale [7-A-67]). Nontornadic winds include straight winds and tropical cyclones. The wind hazard strike definition should include a broad area around the SSCs, as missiles can be generated and transported significant distances (see commentary for SR WFR-E6, below). EPRI ([7-A-81], [7-A-82]) and Sciaudone et al. [7-A-14] illustrate missile-generation areas for plants. Twisdale et al. [7-A-7] illustrates the difference in tornado hazard curves for a small building at a site versus broader plantwide strikes for missile analysis. It is important to note that the tornado hazard data in NUREG/CR-4461 [7-A-63] are for individual buildings and not sitewide missile analysis.

Table 7-A.2.2-6 Commentary to Supporting Requirements for HLR-WFR-E (Cont'd)

Index No. WFR-E	Commentary
WFR-E2	Wind hazard characteristics are important in wind-generated missile fragilities. NUREG/CR-7004 [7-A-77] conclude that average missile speeds are considerably higher in hurricanes than tornadoes. Twisdale [7-A-67] also indicated significant differences in straight wind vs tornadic missile wind fragilities, with straight winds producing higher fragilities in about 70% of the SSCs. The ratio differences between the two, on a target-by-target basis, exceeded factors of 10 for some SSCs. Straight winds cover a larger area and produce more missiles, on average, per event. Tornado winds can produce missiles that can reach high elevations, travel extreme distances, and achieve high velocities. Partial wind directional shielding of an SSC may not reduce the impact of tornado missiles but could have an impact for nontornadic wind missiles. Consequently, although straight winds and tropical cyclone winds cover larger areas of the site than tornadoes, the results to date suggest that there is no single wind hazard that can be used conservatively to produce wind-generated missile fragilities for all wind hazards. In recent HWPRAs, the analysts have developed separate missile fragilities for tornadic and nontornadic hazards (Twisdale [7-A-67]). Nontornadic hazards may include both tropical cyclones and straight winds. In summary, given published results detailing missile fragility dependence on wind hazard, this SR requires justification in order to substitute missile parameters derived from one wind hazard, say tornadoes, for those from another wind hazard, such as tropical cyclones.
WFR-E3	There are many distinct missile types at a nuclear plant site. For example, see EPRI ([7-A-81], [7-A-82]) regarding the need for a broad spectrum of missiles for probabilistic risk analysis of missile effects. Recent papers (Sciaudone et al. [7-A-14], [7-A-87]; Banik et al. [7-A-21]; Twisdale [7-A-67]; and Navarro-Northrup et al. [7-A-88]) emphasize the important role of structure-source missiles, such as metal cladding.
WFR-E4	Structure-source missiles may be one of the most important missile sources at a plant. Roof materials and cladding are elevated above the ground surface, are exposed to higher wind speeds, and have further to fall to reach ground level when transported than missiles that originate near the ground. Progressive failure of the building envelope (Twisdale et al. [7-A-29]; Banik et al. [7-A-21]) provides a ready source of elevated missiles that can transport significant distances at high speeds. Current analyses that consider structure-source missiles indicate that metal roof and wall cladding and associated purlins and girts, and occasionally roof pavers, can provide significant sources of missile risk at nuclear plants.
WFR-E5	The purpose of this SR is to provide justification for the missile-source distance used in the missile fragility analysis. Based on sensitivity analyses, an exclusion distance of 2000 to 2500 ft. to cover the area of risk significance for tornado missiles was suggested in EPRI NP-768 [7-A-81]. A number of recent HWPRAs have used a 2500-ft. exclusion distance from the nearest SSC for sites characterized by small elevation changes. Use of reduced distances may be possible with appropriate analysis and justification. Sites with significant elevation changes and missile sources at high elevations compared with the plant may require an enhanced missile-source distance determination.
WFR-E6	"Scaling" refers to approaches that attempt to use results for one set of plant-specific targets to estimate the missile probabilities for other targets with different areas and missile exposures. There are concerns regarding scaling of missile fragilities for targets of different sizes and exposures. For example, the NRC [7-A-89] expressed concerns regarding improper scaling of area ratios. Sciaudone et al. [7-A-87] provides examples where statistical scaling of results produces errors that can exceed factors of 100 or more for individual plant SSCs. When scaling methods are used, large random and epistemic uncertainties may be generated that need to be evaluated to capture the potential for large errors for individual targets. Certain models (NEI 17-02, [7-A-90]) in the recent literature use original TORMIS data (EPRI [7-A-81], [7-A-82]) for scaling and/or validation. Care is needed in using dated TORMIS results in light of Regulatory Issue Summary 2008-14 [7-A-89] and the fact that the 1978 to 1981 TORMIS examples focused on large targets that were limited in the number of simulations performed and included only a limited number of missiles compared with those used in recent HWPRAs (e.g., not accounting for structure-source missile populations or a full spectrum of missiles in some cases). Recent HWPRAs show that structure-source missile populations can be significant sources of plant missiles, contributing to missile risk (e.g., Twisdale [7-A-67]). Sciaudone et al. [7-A-87] provides detailed discussion of several simplified models and produces comparative statistics. Large aleatory and epistemic uncertainties may be needed for evaluation when models that rely on scaling approaches are utilized.

Table 7-A.2.2-6 Commentary to Supporting Requirements for HLR-WFR-E (Cont'd)

Index No. WFR-E	Commentary	
WFR-E7	Due to the large number of missiles at most sites and the fact that a single missile may damage an SSC, a probabilistic missile analysis should ensure that the results capture the potential for any one missile to produce damage. For example, if there are 100,000 missiles at a site, 1 missile out of 100,000 is 1.0E-5 of the missile distribution function. Thus, this requirement emphasizes the need to demonstrate stable probabilistic results, considering the potentially large number of missile sources. For example, Twisdale et al. [7-A-7] and Twisdale [7-A-67] show tornado missile-analysis results and probabilistic convergence plots using a replication approach to quantifying the standard error in the mean fragilities. The NRC [7-A-88] emphasized the need for convergence in performing missile risk analysis.	
WFR-E8	Wind-generated missile effects (i.e., impact and damage) at a plant are highly dependent on the analysis assumptions and the methodology components. The analyst should specify the assumptions and methods for the components listed under CC-I, which are some of the most important elements of a missile-effects analysis. There are many publications on the subject of wind-generated missiles for tornadoes and other wind hazards. For example, see Tachikawa [7-A-91], Lin et al. [7-A-92], Kordi and Kopp [7-A-93], Crawford [7-A-94], and NEI 17-02 [7-A-90]. Sciaudone et al. [7-A-87] compare missile impact probabilities for several recently developed models used in the nuclear industry.	The distinction between CC-II and CC-I missile-effects analyses includes *(a)* consideration of site-specific shielding structures *(b)* consideration of site-specific missile ricochet into SSCs, if appropriate *(c)* use of site-specific wind hazard path size and path directions *(d)* use of missile-type-dependent aerodynamics *(e)* use of missile damage methods that depend on missile type *(f)* ensuring that the analysis components capture the site-specific and risk-significant 3-D features of the SSCs and the plant The additional CC-II requirements include site-specific hazard and plant geometry components that may be important in the quantification of missile effects. CC-II requires that missile-dependent aerodynamics be used in the trajectory analysis and that missile impact and damage effects be missile-type dependent. CC-II ensures that the analysis method captures the 3-D spatial features of missile sources, trajectories, shielding and ricochet, and SSC locations. Benefits of the CC-II analysis are improved accuracy and reduced uncertainties in the missile-effects analysis. For example, if the CC-II method has validated components, then the use of validated components may be important in the epistemic uncertainty modeling. Validation includes consideration of elements such as the numbers of missiles from source structures, the missile-injection model, the trajectory model, and the damage model. As an illustration of wind-generated missile validation for missile injection, trajectory distances, and missile damage modeling, see EPRI ([7-A-81], [7-A-82]), Twisdale et al. [7-A-77], and FEMA [7-A-95]. Experimental validation and sources of model data are also illustrated by Crawford [7-A-94], Lin et al. [7-A-92], and Kordi and Kopp [7-A-93]. State-of-the-art missile-fragility tools have limitations that can significantly overpredict missile fragilities for equipment deep inside non-Category I buildings. To account for the overconservatism, qualitative considerations could be implemented after performing a full quantitative missile-fragility analysis.

Table 7-A.2.2-6 Commentary to Supporting Requirements for HLR-WFR-E (Cont'd)

Index No. WFR-E	Commentary
WFR-E9	The missile hit/damage criterion must be described for each vulnerable SSC. For example, missile hit might be used for fragile SSCs or as a conservative criterion for all vulnerable SSCs. Penetration, perforation, spall, crimping, and other criteria might be used for SSCs with some degree of hardness. EPRI [7-A-81], [7-A-82] discuss these effects. Bochierri et al. [7-A-96] and Navarro-Northrup et al. [7-A-88] present detailed results from finite element calculation on nuclear plant SSCs.
WFR-E10	Correlated failures of SSCs are an important concern in PRAs. For example, damage to redundant components in an HW event may be a major contributor to plant risk. It is important to identify SSCs that may be subject to correlated missile failures. Close proximity without protection from missiles might indicate a potential positive correlation to missile damage in the same wind event. Therefore, this SR requires a description as to how the missile-fragility analysis considers the potential for multiple SSC failures from wind-generated missiles and why those failures are not statistically dependent. Correlation of missile fragilities may be important in the HWPRA, as many SSCs may be impacted by multiple missiles generated in a wind event. Twisdale et al. [7-A-29] discuss positive and negative missile-fragility correlations and provide some simple correlation bounds.
WFR-E11	The missile populations at a plant vary over the lifetime of the plant. New structures are built; modifications are made; and materials, additional vehicles, and temporary structures and offices are needed for outages. In some cases, significant amounts of materials may be stored near safety-related SSCs. Discussions of the importance of treating these missile-population variations can be found in Sciaudone et al. [7-A-14] and Lovelace et al. [7-A-15].

Table 7-A.2.2-7 Commentary to Supporting Requirements for HLR-WFR-F

Index No. WFR-F	Commentary
WFR-F1	Structural interactions occur when the wind response of an SSC affects the response of other SSCs. For example, the collapse of the roof deck or roof structure could be assumed to fail all the SSCs located underneath. Structural interactions need to be considered based on the location of SSCs within structures and the potential for a structure to collapse onto an adjacent structure. Recent HWPRAs have demonstrated the need for the fragility modeling team to have a clear understanding of the relationship between structural interaction and wind-generated missile fragilities *(a)* to avoid overlooking potential structural interactions and *(b)* to ensure consistent modeling of both structural interaction fragilities and missile fragilities. For example, consider the potential failure of metal wall cladding. If vulnerable SSC "A" is located adjacent to the wall cladding, a potential structural interaction failure mode may include damage to SCC A during the time that the cladding is becoming fully detached from the structural frame. Dynamic motions of the cladding element, while still partially attached to the wall, could produce repeated impacts on a nearby, vulnerable SSC. In this case, ignoring the interaction potential would underestimate the fragility of SSC A. The cladding element may also become fully detached during the storm and transport as a missile, which could potentially hit SSC "B," located some distance away.
WFR-F2	No commentary provided.

Table 7-A.2.2-8 Commentary to Supporting Requirements for HLR-WFR-G

Index No. WFR-G	Commentary
WFR-G1	HWs are often, but not always, accompanied by rain. Wind-driven rain is a potential wind effect that results when HWs produce damage to the plant and rain occurs during or shortly after the occurrence of the damaging winds. Wind-driven rain includes rain that has a horizontal velocity component from wind. This effect is potentially important when electrical equipment vulnerable to water damage is housed in structures with building envelopes that may fail in HWs. HWs could damage the roof cover, roof deck, or wall cladding, allowing wind-driven rainwater to enter the building and saturate the equipment (Twisdale et al. [7-A-29]; Vickery et al. [7-A-8]).

Table 7-A.2.2-8 Commentary to Supporting Requirements for HLR-WFR-G (Cont'd)

Index No. WFR-G	Commentary
WFR-G1 (Cont'd)	Within the context of an HWPRA, wind-driven rain considers rainwater deposition onto the equipment from vertical and horizontal exposure to rain, drip, and spray. Wind-driven rain does not include local flooding from intense rain. Flooding from rain or storm surge is considered a correlated hazard and is treated in Part 8 of this Standard. Wind-driven rain is therefore only considered at wind speeds above V_L, the lower-bound starting wind speed for an HWPRA. Rain effects for all other conditions are not part of an HWPRA scope and are treated in Part 8. Several HWPRAs considered wind-driven rain in a second phase of work. During the first phase, it was assumed that when the building envelope failed, the vulnerable electrical equipment was conditionally failed due to the potential for rainwater damage to the equipment. Subsequent refined analysis, with explicit modeling of envelope failures, wind direction frequency analysis, rain trajectory analysis, and equipment fragility development, produced less conservative fragilities. For example, a detailed wind-driven rain model (Vickery et al. [7-A-8]) showed that the electrical equipment fragilities from wind-driven rain were significantly lower than the fragilities of the enclosing building envelope, especially when directional wind and rain modeling was included in the analysis. There is significant literature on wind-driven rain with regard to building science (e.g., Blocken and Carmeliet [7-A-97]). Information on rainfall rates, total rainfall, storm type, peak gust wind speeds, and so on can be obtained from the National Center for Environmental Information. Other useful references for modeling wind-driven rain effects include Blanchard and Spencer [7-A-98], Blevins [7-A-99], Dingle and Lee [7-A-100], and Willis and Tattleman [7-A-101]. In several HWPRAs, the wind-driven rain analysis was coupled with 3-D progressive-failure building models and directional wind analysis (Vickery et al. [7-A-8]). It is important to note that rain does not always accompany HW events, and the rain probability depends on the wind hazard type. Twisdale et al. [7-A-7] noted that the probability of rain for thunderstorm and extratropical winds (within 24 hours of an HW event) was in the range of 0.4 to 0.6 for several sites analyzed in North America. In addition, wind-driven rain is typically a concern only for electrical equipment that is vulnerable to water deposition and leakage into the interior of the equipment (e.g., slow leakage through openings as a result of air-pressure differences). Motor control centers housed in turbine or other metal-clad buildings have been analyzed at several plants where wind-driven rain analysis was undertaken.
WFR-G2	Building-envelope failures that permit entry of rainwater include failure of the roof cover, roof deck, doors, windows, vents, cladding, and other elements that enclose the building and protect SSCs that are vulnerable to wind-driven rain.

Table 7-A.2.2-9 Commentary to Supporting Requirements for HLR-WFR-H

Index No. WFR-H	Commentary
WFR-H1	Aleatory and epistemic uncertainties in fragility development and/or fragility curves are discussed and illustrated in numerous papers, including Banik et al. [7-A-21], Sciaudone et al. [7-A-14], [7-A-87], Nicholas et al. [7-A-102], Hess et al. [7-A-103], Twisdale et al. [7-A-29], [7-A-7], and Twisdale [7-A-67], [7-A-30].
WFR-H2	No commentary provided.
WFR-H3	Key assumptions and uncertainties regarding HWPRAs are discussed in many of the above papers. Lovelace et al. [7-A-9] provides a useful summary.

Table 7-A.2.2-10 Commentary to Supporting Requirements for HLR-WFR-I

Index No. WFR-I	Commentary
WFR-I1	No commentary provided.
WFR-I2	No commentary provided.

7-A.2.3 COMMENTARY TO WIND PLANT RESPONSE ANALYSIS (WPR)

In order to address to the Wind Plant Response Analysis requirements contained herein, the HWPRA analysis team should possess an internal-events, at-power Level 1 and either a Level 2 or LERF PRA, developed either before or concurrently with the HWPRA. The following assumptions are made:

(a) The internal-events PRA will be used as the basis for the HWPRA systems analysis (if appropriate).

(b) Ideally, the internal-events, at-power PRA (if used) should have been peer reviewed and confirmed to be in compliance with Part 2 of this Standard.

Systems analysis for HWPRAs may include both adding HW-related basic events to the internal-events systems model and "trimming" some aspects of that model that do not apply or may be screened out.

Table 7-A.2.3-1 Commentary to High Level Requirements for Wind Plant Response Analysis (WPR)

Designator	Commentary
HLR-WPR-A	No commentary provided.
HLR-WPR-B	No commentary provided.
HLR-WPR-C	No commentary provided.
HLR-WPR-D	No commentary provided.
HLR-WPR-E	No commentary provided.
HLR-WPR-F	No commentary provided.

Table 7-A.2.3-2 Commentary to Supporting Requirements for HLR-WPR-A

Index No. WPR-A	Commentary
WPR-A1	The purpose of this SR is to ensure that proper consideration is given to the type of HW event being considered. Tornadic events have the ability to lift "missiles" in the wind stream and transport them to elevations much higher than their initial position. Tornadic winds also impose unique motions on the debris and may limit debris speed relative to the peak tornado speed. Straight-wind events typically cover large areas and can produce missiles over wide areas. Straight-wind motions may also allow increased acceleration of missiles over longer distances due to the absence of high rotational winds. The HWPRA includes consideration of HW events when the plant is initially at-power. However, the initiating HW may result in actions to reconfigure or change the operating mode of the plant prior to the onset of the HW-induced initiating event or in response to warnings. Therefore, in addition to initiating events caused directly by the HW event (e.g., loss of off-site power, loss of ultimate heat sink availability, loss of functions due to loss of SSCs), this SR also requires that "indirect" initiating events be considered (e.g., initiating events caused by actions to shut down the plant or isolate the plant from the grid). This SR also recognizes that human actions associated with plant shutdown or other plant HW-response activities may lead to initiating events. It is noted that the failure of certain SSCs may lead to multiple induced initiating events.
WPR-A2	No commentary provided.
WPR-A3	Given the unique challenges that may arise during an HW event, this requirement is intended to ensure that the analyst considers a range of available information sources related to HW-related challenges to the plant. Relevant HW experience may include events experienced at the site as well as industry operating experience. In addition, this SR requires reviewing situations in which actions were taken in response to warnings. This SR requires that these experiences and other available HW risk evaluations be reviewed as part of the development of the HWPRA.
WPR-A4	Coexistent hazards may result in plant effects that are different or more severe than those caused only by HW. In addressing coexistent hazards, it is recommended that the analyst refer to other parts of this Standard (e.g., Part 8 for external flooding).

Table 7-A.2.3-2 Commentary to Supporting Requirements for HLR-WPR-A (Cont'd)

Index No. WPR-A	Commentary
WPR-A5	This SR requires that the initiating events identified in SRs WPR-A1, WPR-A2, and WPR-A3 be included in the HWPRA. This SR refers to risk-significant accident-progression sequences, interpreted as the "minimum" set of accident sequences and/or risk-significant progression sequences for which initiating events must be included in the plant-response model. This SR is not intended to require the exclusion of initiating events associated with non-risk-significant accident-progression sequences. It is recognized that a determination of risk significance may not be apparent at the start of the analysis, but when the final HWPRA is developed, it should contain the risk-significant accident-progression-sequence initiating events.

Table 7-A.2.3-3 Commentary Supporting Requirements for HLR-WPR-B

Index No. WPR-B	Commentary
WPR-B1	No commentary provided.
WPR-B2	The peer review for the PRA used as the base model could include deficiencies that may not yet be resolved. This SR requires that the analyst(s) verify that deficiencies from the peer review of the internal-events PRA, which are relevant to the HWPRA, be addressed. Deficiencies related to PRAs that are irrelevant to an HWPRA (e.g., anticipated transient without scram, certain loss-of-coolant-accident sequences) need not be addressed as part of this SR. In some cases, the disposition of peer-review deficiencies from the internal-events PRA may lead to an update of the HWPRA plant-response model. The definition of "significant deficiency" needs to be considered in the context of the regulatory framework (i.e., on a country-by-country basis). In the US, the PRA peer-review guidance indicates that a finding-level observation impacts the technical adequacy of the PRA and is therefore a significant deficiency. Note that "significant" in this context is not to be strictly intended as risk significant.
WPR-B3	This SR addresses SSC functional failure modes, which are the result of the HW impact on the SSC (e.g., HW-specific mitigation equipment, failure due to overtopping, crimping). This investigation could result in SSC functional-failure modes that were not identified in the internal-events PRA.
WPR-B4	See commentary for SR WPR-A7, which calls for developing the correlations and assessing their impact. SR WPR-B4 calls for modeling them and justifying the approach employed.
WPR-B5	Mission time should consider industry experience in restoring off-site power following various HW intensities. These times should be used in reliability estimates of coping equipment. Coping times > 24 hrs are possible particularly for long-duration events such as hurricanes and extratropical cyclones. Use of convolution in power recovery may be considered to the extent supported by data. CC-I applications may include a single bounding mission time for all HW scenarios. CC-II mission times may be dependent on HW intensity. Where realistic times to power recovery may be less than the internal-events mission time, the internal events mission times should be used.
WPR-B6	No commentary provided.
WPR-B7	Coexistent hazards include wind-driven rain and potential flood surge. INCLUDE does not imply the need for quantitative analyses, unless it is appropriate.
WPR-B8	The intent of this requirement is to ensure that multiunit effects are addressed within the PRA. For example, this SR is intended to ensure *(a)* that resources credited to the unit under analysis would be available, given that other unit(s) might compete for the same resource, and *(b)* that the HWPRA for one unit captures *(1)* the effect of failures at the other unit(s) (e.g., failures of shared SSCs); and *(2)* the effect on site accessibility.

Table 7-A.2.3-4 Commentary to Supporting Requirements for HLR-WPR-C

Index No. WPR-C	Commentary
WPR-C1	The internal-event PRA model is the starting point for developing the HWTL. However, many SSCs that would be pertinent to HW events may not have been identified in the internal-events PRA. Consideration is required for barriers, doors, off-site power lines, tanks, and other equipment uniquely related to HW response. An example approach can be seen in the EPRI HW walkdown guidance document [7-A-16].
WPR-C2	No commentary provided.
WPR-C3	It is expected that utilities with multiple-site PRAs will regard that information as available for review. The intent of this SR is to use other available HWPRA considerations to ensure that certain SSCs that may not be obvious are included the HWEL, if applicable, for the site for which the HWPRA is being performed.
WPR-C4	Structural interactions include impact of building collapse and physical contact of adjacent structures. As these impacts are driven by the proximity of structures, potential spatial interactions should be evaluated thoroughly during the walkdowns.
WPR-C5	This SR addresses SSC functional-failure modes (e.g., failure to open a valve) so as to confirm that the associated fragilities encompass all the SSC supporting components (e.g., instrument air piping).

Table 7-A.2.3-5 Commentary to Supporting Requirements for HLR-WPR-D

Index No. WPR-D	Commentary
WPR-D1	No commentary provided.
WPR-D2	Operator actions evaluated for HWs need to take into account the unique timing and damage aspects of each HW hazard (e.g., straight winds, tornadoes, and hurricanes). For example, tornadoes may occur with very little warning and only impact the plant for a short duration, but hurricanes may come with substantial advanced warning and may impact the plant for a much longer duration.
WPR-D3	No commentary provided.
WPR-D4	No commentary provided.
WPR-D5	The intent of this requirement is to ensure that the interpretation of procedures as well as associated challenges is realistic. Because it is not possible to reasonably simulate many actions under the conditions that will actually be performed (e.g., actions performed under HWs), judgment may be required when assessing manual actions. This SR is intended to strengthen the validity of the assessment by consulting with operators, personnel with knowledge of operations, or other personnel that may be performing actions. For example, response times for human actions taken under HW conditions may increase relative to actions taken under nominal conditions. Moreover, delays in initiation of actions may result in the actions being taken instead under HW conditions rather than as originally planned under nominal conditions or in delaying the initiation of these actions until conditions allow for the action to be performed safely (including transit to the plant location where the action is to be performed).
WPR-D6	No commentary provided.
WPR-D7	No commentary provided.
WPR-D8	No commentary provided.
WPR-D9	If pre-event actions are credited, ensure that adequate warning time is available and that the environment where the action is being performed (e.g., in control room vs. in the yard) is appropriately considered. For actions taken during an HW event, consider the potential for event-related stresses. Postaccident actions should consider the impact of debris and the potential for exterior doorways to be jammed.

Table 7-A.2.3-6 Commentary to Supporting Requirements for HLR-WPR-E

Index No. WPR-E	Commentary
WPR-E1	The PRA systems and accident-sequence model for an HWPRA are commonly based on the internal-events, at-power PRA systems model, to which a number of items are added such as HW initiating events, SSC failure-probability basic events derived from the fragility analysis, and other basic events (e.g., new or adjusted HEPs for the specific hazard). Other factors to be considered include unique aspects of common causes, fragility correlations, any warning time available to take mitigating steps, and the possibility of recovery actions. Internal-events accident-sequence models may also be modified or some sequences not used for a given hazard model. Screening out certain parts of the internal-events systems model from explicit incorporation in a hazard PRA model is common (this screening out can take the form of explicitly deleting the logic in the hazard PRA or bypassing or directly failing the logic, as appropriate). New system fault-tree logic and/or accident-sequence logic may need to be developed and added into the PRA model.
WPR-E2	Certain quantification tools utilize approximations that may cause results to become inaccurate when success branches include basic events with high failure probabilities. In recognition of the possibility of high failure probabilities in conjunction with HW-specific actions or SSCs subjected to HW conditions, this SR is intended to ensure that the analyst considers and addresses the limitations of computational tools when performing quantification.
WPR-E3	During calculation of the wind-speed hazard points to be utilized in the quantification, the points should be discretized appropriately around the plant's unique vulnerabilities so as to allow for convergence of the CDF and LERF. The analyst may demonstrate convergence on the risk metrics by performing sensitivity studies to show that the CDF or LERF does not significantly change with increased discretization. SR QU-B3 of Part 2 recommends a convergence level of 5%. The analyst may choose and justify an alternative convergence level based on HW impacts and total plant CDF.
WPR-E4	This SR requires that the analyst perform appropriate assessments to confirm the correctness of the calculation process. For quantification elements not explicitly considered, the analyst should document the basis for exclusion.
WPR-E5	No commentary provided.
WPR-E6	This SR requires that the analyst perform appropriate assessments to confirm the correctness of the LERF model as applied to HW sequences. The analyst should provide explanation of LERF analysis elements not explicitly considered.
WPR-E7	No commentary provided.
WPR-E8	No commentary provided.

Table 7-A.2.3-7 Commentary to Supporting Requirements for HLR-WPR-F

Index No. WPR-F	Commentary
WPR-F1	Examples of items to be documented include, but are not limited to, *(a)* key findings from walkdowns *(b)* insights from operator interviews, talk-through(s), table-top exercises, or simulation(s), as available, to the extent the actions are credited in the HWPRAs and would be impacted by the presence of HW phenomena *(c)* HW event trees and fault trees *(d)* the specific adaptations made in the internal-events PRA model to produce the HWPRA model, and the basis for those adaptations, or a description of ad hoc models developed specifically for the HWPRA *(e)* the basis for selection of SSCs included in the HWPRA and associated fragilities of those SSCs *(f)* the specific HW-related influences that affect methods, processes, or assumptions used and the identification and quantification of the HFEs *(g)* the recovery human actions included in the plant-response model *(h)* the preparatory human actions included in the plant-response model *(i)* significant risk contributors in the HWPRA model
WPR-F2	No commentary provided.

7-A.3 REFERENCES

The following list of publications is referenced in this Appendix.

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[7-A-2] U.S. Nuclear Regulatory Commission (NRC), 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," 1971; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[7-A-3] ASCE/SEI-7-16, "Minimum Design Loads for Buildings and Other Structures," 2017; American Society of Civil Engineers (ASCE), Structural Engineering Institute (SEI),1801 Alexander Bell Drive, Reston, VA 20191-4400

[7-A-4] NUREG/CR-7005, "Technical Basis for Regulatory Guidance on Design-Basis Hurricane Wind Speeds for Nuclear Power Plants," P. J. Vickery, D. Wadhera, and L. A. Twisdale, November 2011; U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

[7-A-5] L. Phan, M. Levitan, and L. A. Twisdale, "Tornado Hazard Mapping for Tornado-Resistant Design of Buildings and Infrastructure," presented at the 28th Conference on Severe Local Storms, Portland, OR, November 7–11, 2016; American Meteorological Society (AMS), 45 Beacon Street Boston, MA 02108-3693, https://ams.confex.com/ams/28SLS/webprogram/Paper300998.html (current as of January 15, 2022)

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[7-A-10] Glossary of Meteorology, "tornado," October 2013; American Meteorological Society (AMS), 45 Beacon Street Boston, MA 02108-3693, http://glossary.ametsoc.org/wiki/ (current as of January 14, 2022)

[7-A-11] T. T. Fujita, "Proposed Characterization of Tornadoes and Hurricanes by Area and Intensity," Satellite and Mesometeorology Research Project (SMRP) Research Paper No. 91, February 1971; University of Chicago, 5801 S. Ellis Ave., Chicago, IL 60637

[7-A-12] "Enhanced Fujita Scale (EF-Scale)," Rev. 2, October 2006; Texas Tech University, Wind Science and Engineering Center, 2500 Broadway, Lubbock, TX 79409, https://www.spc.noaa.gov/efscale/ef-ttu.pdf (current as of January 14, 2022)

[7-A-13] ASCE/SEI 7-10, "Minimum Design Loads for Buildings and Other Structures," 2013; American Society of Civil Engineers (ASCE), Structural Engineering Institute (SEI), 1801 Alexander Bell Drive, Reston, VA 20191-4400

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[7-A-16] EPRI Report 3002008092, "High Wind Equipment List and Walkdown Guidance," December 2016; Electric Power Research Institute (EPRI), 3420 Hillview Avenue, Palo Alto, CA 94304-1388

[7-A-17] JCNRM Inquiry Record 20-2435, The American Society of Mechanical Engineers (ASME) and the American Nuclear Society (ANS), Joint Committee Nuclear Risk Management (JCNRM) Inquiries and Interpretations, ASME website link: https://cstools.asme.org/csconnect/CommitteePages.cfm?Committee=100186782&Action=40886

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