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December 9, 2021

Subject: Submittal of the Westinghouse **eVinci**™ Micro-Reactor Group 1 White Papers for Pre-Application Engagement

I am pleased to submit on behalf of Westinghouse Electric Company the four enclosed **eVinci** micro-reactor white papers. These four white papers represent a significant step for the project in supporting early pre-application engagement with the NRC. The papers describe the **eVinci** micro-reactor design and methodologies. Specifically, this submittal includes the following topics: facility-level design description (Enclosure 3), principal design criteria (Enclosure 4), safety and accident analysis methodologies (Enclosure 5), and licensing basis event identification, SSC classification and defense-in-depth adequacy (Enclosures 6 and 7). This is the first group of white papers to be submitted to the NRC to support on-going preapplication discussions. Future groups of papers on additional **eVinci** micro-reactor topics will be submitted to the NRC, as communicated in the Regulatory Engagement Plan submitted to the NRC on November 22, 2021.

The goal of these white papers is to facilitate pre-application discussions and receive regulatory feedback on the **eVinci** micro-reactor design and methodologies. To support this goal, Westinghouse seeks NRC review and written feedback on these white papers by February 2022.

This submittal contains proprietary information of Westinghouse Electric Company LLC ("Westinghouse"). In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Nuclear Regulatory Commission's ("Commission's") regulations, we are enclosing with this submittal an Affidavit. The Affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

Correspondence with respect to the proprietary aspects of this submittal or the Westinghouse Affidavit should reference AW-21-5246 and should be addressed to Anthony J. Schoedel, Manager, Advanced Reactors Licensing Engineering, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 1, Cranberry Township, PA 16066.

Anthony J. Schoedel, Manager
Advanced Reactors Licensing Engineering

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Enclosures:

1. Affidavit AW-21-5246
2. Proprietary Information Notice and Copyright Notice
3. EVR-LIC-G0-001, Revision 0, "Facility Level Design Description" (Proprietary)
4. EVR-LIC-GL-003, Revision 0, "Principal Design Criteria" (Proprietary)
5. EVR-SAR-GL-001, Revision 0, "Safety and Accident Analysis Methodologies" (Proprietary)
6. EVR-SAR-GL-002, Revision 0, "Licensing Basis Event Identification, SSC Classification and Defense-in-Depth Adequacy" (Proprietary)
7. EVR-SAR-GL-002-NP, Revision 0, "Licensing Basis Event Identification, SSC Classification and Defense-in-Depth Adequacy" (Non-Proprietary)

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:
COUNTY OF BUTLER:

(1) I, Anthony J. Schoedel, have been specifically delegated and authorized to apply for withholding and execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse).

(2) I am requesting the proprietary portions of EVR-LIC-G0-001 Revision 0, EVR-LIC-GL-003 Revision 0, EVR-SAR-GL-001 Revision 0, and EVR-SAR-GL-002 Revision 0 be withheld from public disclosure under 10 CFR 2.390.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged, or as confidential commercial or financial information.

(4) Pursuant to 10 CFR 2.390, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse and is not customarily disclosed to the public.

(ii) The information sought to be withheld is being transmitted to the Commission in confidence and, to Westinghouse's knowledge, is not available in public sources.

(iii) Westinghouse notes that a showing of substantial harm is no longer an applicable criterion for analyzing whether a document should be withheld from public disclosure. Nevertheless, public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar technical evaluation justifications and licensing defense services for commercial power reactors without

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commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

(5) Westinghouse has policies in place to identify proprietary information. Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage (e.g., by optimization or improved marketability).

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

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(6) The attached document EVR-SAR-GL-002 Revision 0 is bracketed and marked to indicate the bases for withholding. The justification for withholding is indicated in both versions by means of lower-case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower-case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (5)(a) through (f) of this Affidavit.

(7) The attached submittal EVR-LIC-G0-001 Revision 0, EVR-LIC-GL-003 Revision 0, and EVR-SAR-GL-001 Revision 0 contains proprietary information throughout, for the reasons set forth in Sections (5)(a) through (f) of this Affidavit. Accordingly, a redacted version would be of no value to the public.

I declare that the averments of fact set forth in this Affidavit are true and correct to the best of my knowledge, information, and belief.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on: 12/9/2021

Anthony J. Schoedel, Manager
Advanced Reactors Licensing Engineering

Enclosure 2

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are the proprietary and non-proprietary versions of a document, furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the Affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).

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The reports transmitted herewith each bear a Westinghouse copyright notice. The NRC is permitted to make the number of copies of the information contained in these reports which is necessary for its internal use in connection with generic and plant specific reviews and approvals as well as the issuance, denial, amendment, transfer, renewal, modification, suspension, revocation, or violation of a license, permit, order, or regulation subject to the requirements of 10 CFR 2.390 regarding restrictions on public disclosure to the extent such information has been identified as proprietary by Westinghouse, copyright protection notwithstanding. With respect to the non-proprietary version of this report, the NRC is permitted to make the number of copies beyond those necessary for its internal use which are necessary in order to have one copy available for public viewing in the appropriate docket files in the public document room in Washington, DC and in local public document rooms as may be required by NRC regulations if the number of copies submitted is insufficient for this purpose. Copies made by the NRC must include the copyright notice in all instances and the proprietary notice if the original was identified as proprietary.

Enclosure 7

EVR-SAR-GL-002-NP, Revision 0

“Licensing Basis Event Identification, SSC Classification and Defense-in-Depth Adequacy”

(Non-Proprietary)

Westinghouse Electric Company
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REVISION SUMMARY

Revision	Revision Description
0	Initial Issue

OPEN ITEMS

Open Item #[1]	Section	Open Item Description	Status
1	All	The information contained herein represents the intended processes to be followed based on the current state of the **eVinci**™ micro-reactor development program. The processes identified herein are generally technology neutral, however, there is the potential that deviations may be necessary as the design continues to develop and/or execution of the processes results in yet to be identified issues.	Open

[1]This is an initial issue developed during the conceptual and preliminary design phases. Commensurate with the development of the design interfaces, open items are not yet tracked for the project. Future revisions of this document will track open items according to applicable procedures.

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Acronyms and Trademarks

Acronyms used in the document are included below to ensure unambiguous understanding of their use within this document.

Acronym	Definition
ACS	Autonomous Control System
ADAMS	Agencywide Documents Access and Management System [NRC document repository]
AGR	Advanced Gas-cooled Reactor
ANS	American Nuclear Society
AOO	Anticipated Operational Occurrences
ASME	American Society of Mechanical Engineers
BDBE	Beyond Design Basis Event
CCS	Canister Containment System
CFR	Code of Federal Regulations
DBA	Design Basis Accident
DBE	Design Basis Event
DBHL	Design Basis Hazard Levels
DID	Defense-in-depth
EAB	Exclusion Area Boundary
EDU	Electrical Demonstration Unit
EPS	Electrical Power System
F-C	Frequency-Consequence
FMEA	Failure Modes and Effects Analysis
FR	Federal Register
IAEA	International Atomic Energy Agency
ICE	Instrumentation, Control and Electrical
IDP	Integrated Decision-making Panel
IE	Initiating Event
IGS	Inert Gas System
LBE	Licensing Basis Event
LCS	Local Control Station
LLC	Limited Liability Company
LMP	Licensing Modernization Program
LWR	Light Water Reactor
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
NSRST	Non-Safety-Related with Special Treatment
NST	Non-Safety-Related with No Special Treatment
PAM	Post-Accident Monitoring
PCS	Power Conversion System
PDC	Principal Design Criteria
PHS	Passive Heat Removal System
PHX	Primary Heat Exchanger
PIRT	Phenomena Identification Ranking Table
PRA	Probabilistic Risk Assessment
PSF	PRA Safety Functions
QHO	Quantitative Health Objective
RG	Regulatory Guide
RFDC	Required Function Design Criteria
RIPB	Risk-informed, Performance Based
RSF	Required Safety Function
RXS	Reactor System
SR	Safety-related
SRDC	Safety-related Design Criteria
SSC	System, Structure, Component
SiC	Silicon Carbide
TRISO	Tri-structural Isotropic
UCA	Unit Cell Assembly

Glossary of Terms

The terminology used herein is that of Nuclear Energy Institute (NEI) 18-04, "Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development" (Reference 1) unless otherwise indicated. Key standard terms used in the document are included below to ensure unambiguous understanding of their use within this document.

Term	**Definition**
Anticipated Operational Occurrences (AOOs)	Event sequences with mean frequencies of 1×10^{-2} /facility-year and greater are classified as AOOs. AOOs take into account the expected response of all Systems, Structures, and Components (SSCs) within the facility, regardless of safety classification.
Beyond Design Basis Events (BDBEs)	Event sequences with mean frequencies of 5×10^{-7} /facility-year to 1×10^{-4} /facility-year are classified as BDBEs. BDBEs take into account the expected response of all SSCs within the facility regardless of safety classification.
Design Basis Events (DBEs)	Event sequences with mean frequencies of 1×10^{-4} /facility-year to 1×10^{-2} /facility-year are classified as DBEs. DBEs take into account the expected response of all SSCs within the facility regardless of safety classification.
Safety-related (SR) SSCs	SSCs that are credited in the fulfillment of RSFs and are capable to perform their RSFs in response to any Design Basis External Hazard Level.
Non-Safety-Related with Special Treatment (NSRST)	Non-safety-related SSCs that perform risk-significant functions or perform functions that are necessary for defense-in-depth adequacy.
Non-Safety-Related with No Special Treatment (NST)	All SSCs within a facility that are neither Safety-Related SSCs nor Non-Safety-Related SSCs with Special Treatment SSCs.

References

Following is a list of references used throughout this document.

1. NEI 18-04, Rev. 1, "Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development," August 2019 (Available via NRC ADAMS Accession Number ML19241A472).
2. Regulatory Guide 1.233, Rev. 0, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approval for Non-Light-Water Reactors," June 2020 (Available via NRC ADAMS Accession Number ML20091L698).
3. NUREG/CR-3862, "Development of Transient Initiating Event Frequencies for Use in Probabilistic Risk Assessments," May 1985 (Available via NRC ADAMS Accession Number ML20127C938).
4. NUREG/CR-5750, "Rates of Initiating Events at U.S. Nuclear Power Plants: 1978 – 1995," February 1999 (Available via NRC ADAMS Accession Number ML061860698).
5. NUREG/CR-6928, "Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants," February 2007 (Available via NRC ADAMS Accession Number ML070650650).
6. ASME/ANS RA-S-1.4-2020, "Probabilistic Risk Assessment Standard for Advanced Non-LWR Nuclear Power Plants," (updated for NRC endorsement, Fall 2020).
7. Regulatory Guide 1.203, "Transient and Accident Analysis Methods," December 2005 (Available via NRC ADAMS Accession Number ML053500170).
8. Regulatory Guide 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant Specific Changes to the Licensing Basis," January 2018 (Available via NRC ADAMS Accession Number ML17317A256).
9. 51 FR 30028, "Safety Goals for the Operations of Nuclear Power Plants," August 1986.
10. 73 FR 60612, "Policy Statement on the Regulation of Advanced Nuclear Reactors," October 2008.
11. [ ]a,c,e
12. EVR-SAR-GL-001, Rev. 0, "Safety and Accident Analysis Methodologies"
13. EPRI-AR-1(NP), "Uranium Oxycarbide (UCO) Tristructural Isotropic (TRISO) Coated Particle Fuel Performance," May 2019.
14. EVR-LIC-GL-003, Rev. 0, "Principal Design Criteria"

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19. EVR-LIC-GL-001, Rev. 0 "Facility Level Design Description"

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26. NEI 21-07, "Technology Inclusive Guidance for Non-Light Water Reactors: Safety Analysis Report Content for Applicants Using the NEI 18-04 Methodology," August 2021.
27. Final Safety Evaluation for EPRI TRISO Topical Report ((Available via NRC ADAMS Accession Number ML20216A453)
28. INL/EXT-11-22708, "Modular HTGR Safety Basis and Approach," Idaho National Laboratory, August 2011.

1.0 Introduction

1.1 Purpose

The **eVinci™** micro-reactor under development by Westinghouse Electric Company, LLC (Westinghouse) and its partners is a paradigm shifting nuclear technology that has the potential to significantly broaden the market for nuclear generated electricity. Although the technology is paradigm shifting, the commitment to developing a safe reactor is unchanged. The safety demonstration for the **eVinci** micro-reactor technology will utilize many of the same principles of traditional nuclear reactors, but with a slightly different approach given the innovative nature of the eVinci technology.

This white paper is intended to facilitate initial regulatory discussions associated with key pieces of the content of a future application and how the designers intend to satisfy the necessary regulatory requirements (e.g.,10 CFR 50.34 / 10 CFR 52.47). The white paper explicitly presents the intended processes for developing the following:

- The selection of Licensing Basis Events (LBEs), which include AOOs, DBEs, and BDBEs, based on a systematic assessment of operational accidents, natural events, and man-made external events. The down selection of events based on those that are representative and unique. The process for developing these items is described in Section 2.0.
- The classification of SSCs based on the need for mitigation to maintain radiological consequences within the evaluation guideline. The SSC classification process is described in Section 3.0.
- An evaluation of defense-in-depth (DID) adequacy. The process for evaluating DID adequacy is described in Section 4.0.

The processes described herein are based primarily on those developed by industry during the Licensing Modernization Program (LMP). The LMP is a risk -informed and performance-based (RIPB) framework developed by the nuclear industry in NEI 18-04 "Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development" (Reference 1). Regulatory Guide (RG) 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approval for Non-Light-Water Reactors" (Reference 2) provides NRC endorsement of the principles and methodology documented in NEI 18-04 (Reference 1).

1.1.1 Request for NRC

Westinghouse is providing this white paper to the NRC to facilitate discussions regarding the **eVinci** micro-reactor design. Specifically, Westinghouse has the following goals for submitting this white paper and is requesting the following from NRC:

- To keep NRC informed of the process Westinghouse is following to identify LBEs, classify SSCs and evaluate DID adequacy.
- Based on the review of the contents of this white paper, and subsequent pre-application discussions, Westinghouse is requesting NRC feedback and observations on the approach and information discussed herein. In addition, Westinghouse is looking for feedback from NRC on the following specific questions:
    - Does NRC find the process described herein an acceptable way to identify LBEs for the **eVinci** micro-reactor?
    - Does NRC find the process described herein an acceptable way to classify **eVinci** micro-reactor SSCs?

- Does NRC find the process described herein an acceptable way to evaluate the adequacy of the DID equipment for the **eVinci** micro-reactor?
- Are there any aspects of the **eVinci** micro-reactor design that appear to prevent adherence to the NEI 18-04 (Reference 1) and RG 1.233 (Reference 2) guidance?

1.2 Scope

The current revision of this paper is intended to present the process for identifying and addressing LBEs for the eVinci design, rather than the results of the process for the **eVinci** micro-reactor design. Subsequent revisions and/or other regulatory submittals will apply the process to demonstrate reactor-specific analysis and results.

The information included in this white paper is intended to provide identification of the key tasks of the process. The exclusion of NEI 18-04 (Reference 1) text corresponding to the steps indicated herein is not an indication that the specific NEI 18-04 (Reference 1) guidance will not be followed rather simply reflects a distillation of the information into key tasks that comprise the processes.

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In addition to this white paper, there are several additional papers planned to support other topics related to the discussion herein. These additional papers also have key roles in summarizing the facility design and the strategies to be used to demonstrate the safety of the **eVinci** micro-reactor. These papers include:

- EVR-SAR-GL-001, "Safety and Accident Analysis Methodologies" (Reference 12)
- EVR-LIC-GL-003, "Principal Design Criteria" (Reference 14)

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- EVR-LIC-GL-001, "Facility Level Design Description" (Reference 19)

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2.0 Selection of Licensing Basis Events

2.1 Process for Selection of Licensing Basis Events

The selection of LBEs generally follows the tasks laid out in Section 3 of NEI 18-04 (Reference 1), which is depicted in Figure 3-2 of Reference 1 and echoed herein as Figure 2.1-1.

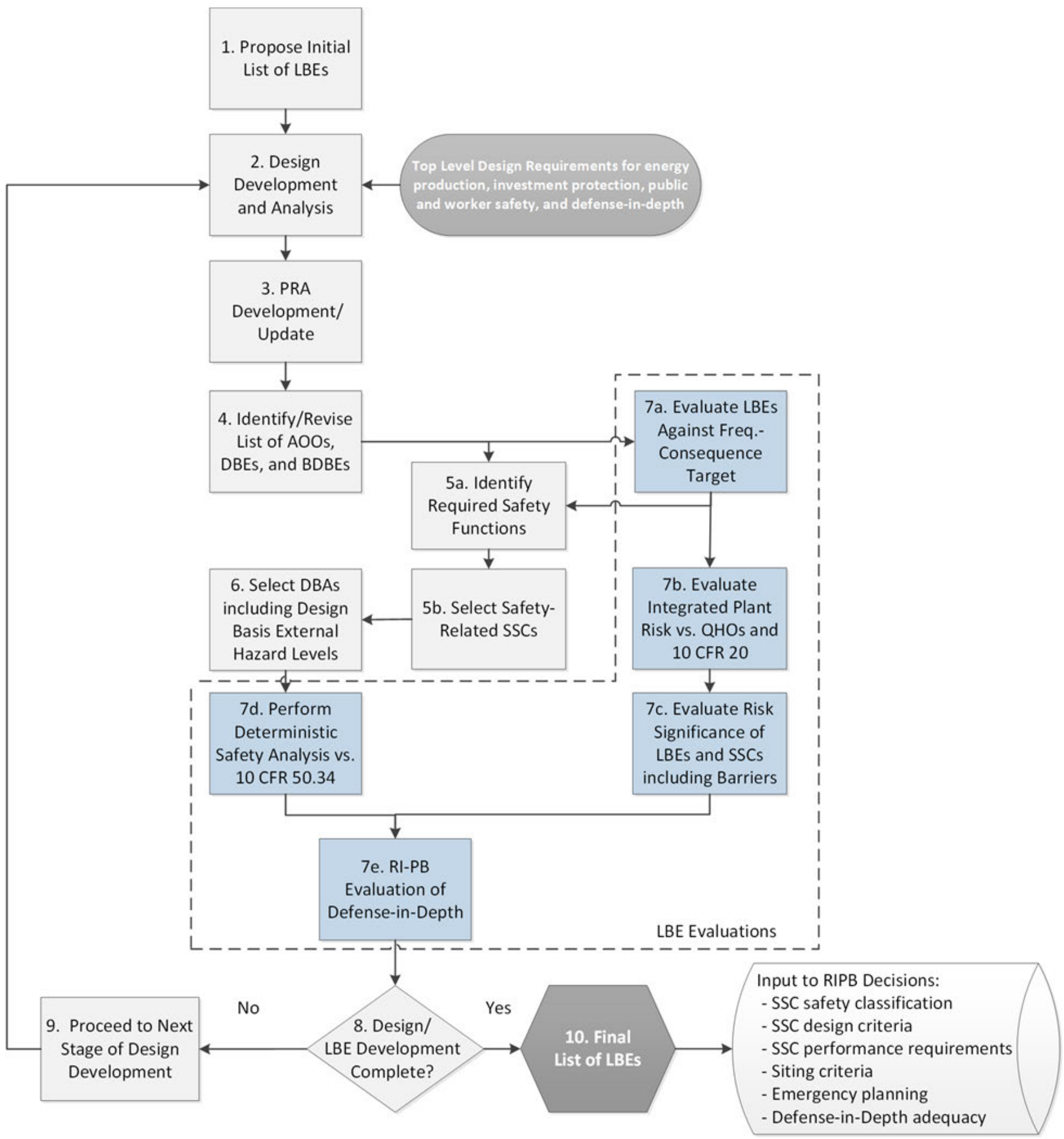

Figure 2.1-1: Process for Selecting and Evaluating Licensing Basis Events

Additional details related to these tasks are provided below.

Task 1: Identification of Initial List of Licensing Basis Events

During design development, it is necessary to select an initial set of LBEs to develop the basic elements of the safety case. Each LBE is defined by an Initiating Event (IE) plus the mitigation systems involved in responding to the IE. Through the NEI 18-04 (Reference 1) process, the LBEs are used as the basis to determine which functions/SSCs are risk-significant and/or safety-related. The initial identification of LBEs for the **eVinci** micro-reactor follows two parallel paths:

- A systematic review of available literature associated with initiating events.
- A structured and multi-disciplinary Failure Mode and Effects Analysis (FMEA) of the design.

A review of available nuclear power facility initiating event literature (References 3, 4, and 5) is performed considering the design of the micro-reactor to obtain the first set of initiating events for consideration.

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Following the completion of the two parallel paths described above, the two lists of potential events are combined and compared to obtain one set of initiators. The initiators are then grouped into event categories based on similar expected facility response.

Task 2: Design Development and Analysis

Design development is performed in phases including a pre-conceptual, conceptual, preliminary, and final design phase each of which may include iterations within phases. Design development and analysis includes definition of the elements of the safety design approach, the design features to meet the top-level design requirements for energy production and investment protection, analyses to develop sufficient understanding to perform a PRA and the deterministic safety analyses. The subsequent Tasks 3 through 10 may be repeated for each design phase or iteration until the list of LBEs becomes stable and is finalized. Because the selection of deterministic DBAs requires the selection of safety-related SSCs, this process also yields the selection of safety-related SSCs that are needed for the deterministic safety analysis in Task 7d.

Task 3: PRA Development/Update

A PRA is built following the high-level structure of American Society of Mechanical Engineers (ASME)/American Nuclear Society (ANS) RA-S-1.4-2020, "Probabilistic Risk Assessment Standard for Advanced Non-LWR Nuclear Power Plants" (Reference 6). The LBEs developed in Task 1 are run through the PRA with the LBEs defined in terms of successes and failures of SSCs that perform safety functions.
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Task 4: Identify/Revise List of AOOs, DBEs, and BDBEs

The PRA and radiological consequences associated with the LBEs performed are plotted against the frequency-consequence (F-C) targets depicted in Figure 2.1-2. [ ]a,c,e The figure highlights only those sequences that fall into the regions of concern as documented in NEI 18-04 (Reference 1). Subsequent tasks are only performed using the results within these regions of concern.

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Figure 2.1-2: Focused Frequency-Consequence Target

Task 5a: Identify Required Safety Functions

Required Safety Functions (RSFs) are those functions necessary and sufficient to meet the F-C Target for all DBEs and high-consequence BDBEs. High-consequence BDBEs are defined as those BDBEs with consequences that exceed the F-C Target. Figure 2.1-3 documents the portions of the F-C Target figure where RSFs are needed (see the yellow highlighted regions). [

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Figure 2.1-3: Regions to consider for RSFs

Task 5b: Select/Revise Safety-Related SSCs

For each of the RSFs identified by completing Task 5a, a decision is made on which set of SSCs is selected to perform the RSFs among those found to be available for each DBE. Each DBE is, therefore, protected by a set of safety-related SSCs to perform each RSF. Structures and physical barriers that are necessary to protect any safety-related SSC in performing their RSF in response to any design basis external event are also classified as safety-related. Safety-related SSCs are also selected for any RSF associated with any high-consequence BDBEs in which the reliability of the SSC is necessary to keep the event in the BDBE frequency region. The remaining SSCs that are not classified as safety-related are considered in other evaluation tasks including Tasks 7b, 7c, 7d, and 7e. The performance targets and design criteria for both safety-related and non-safety-related SSCs are developed applying the approach described in Section 3.1.

Task 6: Select Deterministic DBA and Design Basis Hazard Levels

For each DBE identified in Task 4, a deterministic DBA is defined that includes the RSF challenges represented in the DBE but assumes that the RSFs are performed exclusively by safety-related SSCs, and all non-safety-related SSCs actively performing these same functions are assumed to be unavailable. These DBAs are then used in DBA analysis of the license application for supporting the conservative deterministic safety analysis. Additional details related to deterministic DBA analysis are described in EVR-SAR-GL-001 (Reference 12).

A set of Design Basis Hazard Levels (DBHLs) will be selected to form an important part of the safety case. This will determine the design basis seismic events and other external events that the SR SSCs will be required to withstand. [

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Task 7a: Evaluate LBEs Against F-C Target

In this task, the results of the PRA which have been organized into LBEs are evaluated against the F-C Target presented in Task 4 as Figure 2.1-2.

Figure 2.1-2 does not define specific acceptance criteria for the analysis of LBEs but rather serves as a tool to focus the attention of the designer and those reviewing the design and related operational programs to the most significant events and possible means to address those events. The NRC's Advanced Reactor Policy Statement 73 FR 60612, "Policy Statement on the Regulation of Advanced Nuclear Reactors" (Reference 10) includes expectations that advanced reactors should provide enhanced margins of safety. The safety margin between the design-specific PRA results and the F-C Target provides one useful and practical demonstration of how the design fulfills the NRC's expectations for enhanced safety. These margins also are useful in the evaluation of DID adequacy in Task 7d. The evaluations in this task are performed for each LBE separately. The mean values of the frequencies are used to classify the LBEs into AOO, DBE, and BDBE categories. However, when the uncertainty bands defined by the 5th percentile and 95th percentile of the frequency estimates straddles a frequency boundary, the LBE is evaluated in both LBE categories. An LBE with mean frequency above 10^{-2}/facility-year and 5th percentile less than 10^{-2}/facility-year is evaluated as an AOO and DBE. An LBE with a mean frequency less than 10^{-4}/facility-year with a 95th percentile above 10^{-4}/facility-year is evaluated as a BDBE and a DBE. Uncertainties about the mean values are used to help evaluate the results against the frequency-consequence criteria and to identify the margins against the criteria.

DBE doses are evaluated against the F-C Target based on the mean estimates of consequence. This approach is based on the fact that the use of a conservative dose evaluation is appropriate for the deterministic safety analysis in Task 7a but is not consistent with the way in which uncertainties are addressed in risk-informed decision-making in general, where mean estimates supported by a robust uncertainty analysis are generally used to support risk significance determinations. When evaluating risk significance, comparing risks against safety goal quantitative health objectives (QHOs), and evaluating changes in risk against the Regulatory Guide 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant Specific Changes to the Licensing Basis" (Reference 8) change in risk

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criteria, the accepted practice has been to first perform a quantitative uncertainty analysis and then to use the mean values to compare against the various goals and criteria, which are set in the context of uncertainties in the risk assessments. These assessments apply to both the frequency and consequence estimates.

The primary purpose of comparing the frequencies and consequences of LBEs against the F-C Target is to evaluate the risk significance of individual LBEs. The objective for this activity is to ensure uncertainties in the risk assessments are evaluated and included in discussions of design features and operational programs related to the most significant events and possible compensatory measures to address those events. The evaluations in this task are based on mean frequencies and mean doses for all three LBE categories. Two exceptions to this are when BDBEs with large uncertainties in their frequencies are evaluated as DBEs when the upper 95th percentile of the frequency exceeds 10^{-4}/facility-year and when AOOs with lower 5th percentile frequencies, below 10^{-2}/facility-year, are also evaluated as DBEs. The uncertainties about these means are considered as part of the RIPB DID evaluation in Task 7e.

Task 7b: Evaluate Integrated Facility Risk vs. QHOs and 10 CFR 20

The integrated facility risk is evaluated against QHOs in this step to ensure the proper risk balance is achieved. The QHOs are based, in part, on those in the NRC Safety Goal Policy Statement, 51 FR 30028, "Safety Goals for the Operations of Nuclear Power Plants" (Reference 9), which are as follows:

- The risk to an average individual in the vicinity of a nuclear power facility of prompt fatality resulting from reactor accidents should not exceed one-tenth of one percent (0.1%) of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed.
- The risk to the population in the area of nuclear power facility of cancer fatalities that might result from nuclear power facility operation should not exceed one-tenth of one percent (0.1%) of the sum of cancer fatality risks resulting from all other causes.

These QHOs are translated to the following numerical objectives, which are consistent with NEI 18-04 (Reference 1):

- The average individual risk of early fatality within 1 mile of the Exclusive Area Boundary (EAB) from all LBEs based on mean estimates of frequencies and consequences shall not exceed 5×10^{-7} per facility-year to ensure that the NRC safety goal QHO for early fatality risk is met.
- The average individual risk of latent cancer fatalities within 10 miles of the EAB from all LBEs based on mean estimates of frequencies and consequences shall not exceed 2×10^{-6} /facility-year to ensure that the NRC safety goal QHO for latent cancer fatality risk is met.

In addition to the numerical objectives described above, the following additional objective is selected to confirm that the 100 mrem annual cumulative exposure limit from 10 CFR 20 is met:

- The total mean frequency of exceeding a site boundary dose of 100 mrem from all LBEs should not exceed 1/facility-year. This metric is introduced to ensure that the consequences from the entire range of LBEs from higher frequency, lower consequences to lower frequency, higher consequences are considered.

The 10 CFR 20 criterion is considered in recognition that the referenced regulatory requirement is for the combined exposures from all releases even though it has been used in developing the F-C Target used for evaluating the risks from individual LBEs.

In evaluating the integrated risk design features responsible for preventing and mitigating radiological releases and for meeting the integrated risk criteria are identified. This evaluation leads to performance

requirements and design criteria that are developed within the process of the SSC classification task in the guidance document.

Task 7c: Evaluate Risk Significance of LBEs and SSCs including Barriers

In this task, the details of the definition and quantification of each of the LBEs in Task 7a and the integrated risk evaluations of Task 7b are used to define both the absolute and relative risk significance of individual LBEs and SSCs including radionuclide barriers. These evaluations include the use of PRA risk importance metrics, where applicable, and the examination of the effectiveness of each of the layers of defense in retaining radionuclides. LBEs are classified as risk-significant if the LBE site boundary dose exceeds 2.5 mrem over 30 days and the frequency of the dose is within 1% of the F-C Target. SSCs are classified as risk-significant if the SSC function is necessary to keep any LBEs inside the F-C Target, or if the total frequency of LBEs with the SSCs failed is within 1% of any of the three cumulative risk targets identified in Task 7b. This information is used to provide risk insights, to identify safety-significant SSCs, and to support the RIPB evaluation of DID in Task 7e.

Task 7d: Perform Deterministic Safety Analysis Against 10 CFR 50.34

This task relates to traditional deterministic safety analysis. Additional details related to deterministic safety analysis are described in EVR-SAR-GL-001 (Reference 12).

Task 7e: Risk-Informed, Performance-Based Evaluation of Defense in Depth

Section 4.0 describes the details associated with the evaluation of DID adequacy.

Task 8: Decide on Completion of Design/LBE Development

The purpose of this task is to decide if additional design development is needed, either to proceed to the next logical stage of design or to incorporate feedback from the LBE evaluation that design, operational, or programmatic improvements should be considered. Such design improvements could be motivated by a desire to increase margins against the frequency-consequence criteria, reduce uncertainties in the LBE frequencies or consequences, manage the risks of multi-reactor module events, limit the need for restrictions on siting or emergency planning, or enhance the performance against DID criteria. The DID adequacy evaluation may result in the need for additional iterations on the adequacy of design, operational, and programmatic programs, which in turn could influence the PRA and result in a need for cycling through some or all the LBE evaluation tasks.

Task 9: Proceed to Next Stage of Design Development

The decision to proceed to the next stage of design is reflected in this task. This implies not only completion of the design but also confirmation that DID criteria evaluated in Task 7e have been satisfied. Open items or unverified assumptions will be resolved at later stages of design development.

Task 10: Finalize List of LBEs and Safety-Related SSCs

Establishing the final list of LBEs and safety-related SSCs signifies the completion of the LBE selection process and the selection of the SR SSCs. Completion of the SSC safety classification process, performance requirement formulation and design criteria definition for SSCs that are necessary to control the LBE frequencies and doses and other performance standards associated with the protection of fission product barriers are included in this task. Important information from Task 7a through 7e is used to risk inform the design during this process.

3.0 Safety Classification and Performance Criteria for SSCs

3.1 Process for Safety Classification and Performance Criteria for SSCs

The safety classification approach is described in this section. The **eVinci** micro-reactor uses a risk-informed safety classification approach for SSCs consistent with the guidance provided in NEI 18-04 (Reference 1).

The safety classification categories of NEI 18-04 (Reference 1) have been adopted for the **eVinci** micro-reactor program. The categories are as follows:

- SR:
  - SSCs selected by the designer from the SSCs that are available to perform the RSFs to mitigate the consequences of DBEs to within the LBE F-C Target, and to mitigate DBAs that only rely on the SR SSCs to meet the dose limits of 10 CFR 50.34 using conservative assumptions.
  - SSCs selected by the designer and relied on to perform RSFs to prevent the frequency of BDBEs with consequences greater than the 10 CFR 50.34 dose limits from increasing into the DBE region and beyond the F-C Target.
- NSRST:
  - Non-safety-related SSCs relied on to perform risk-significant functions. Risk-significant SSCs are those that perform functions that prevent or mitigate any LBE from exceeding the F-C Target or make significant contributions to the cumulative risk metrics selected for evaluating the total risk from all analyzed LBEs.
  - Non-safety-related SSCs relied on to perform functions requiring special treatment for DID adequacy.
- NST:
  - All other SSCs (with no special treatment required).

The LMP process for selecting LBEs is described in Section 2.1 and summarized by the chart shown in Figure 2.1-1 (Figure 3-2 from Reference 1). Steps 5a (Identify Required Safety Functions) and 5b (Select/Revise Safety-Related SSCs) are performed within this safety classification process. The results from the safety classification process are used as an input back to the LMP process of selecting the DBAs (Step 6) and ultimately finalizing the list of LBEs (Step 10).

The SSC safety classification process presented in NEI 18-04 (Reference 1) is implemented in the tasks shown in Figure 3.1-1 (Figure 4-1 from Reference 1). These tasks are discussed in more detail in the following sections including how these steps are implemented for the **eVinci** micro-reactor safety classification.

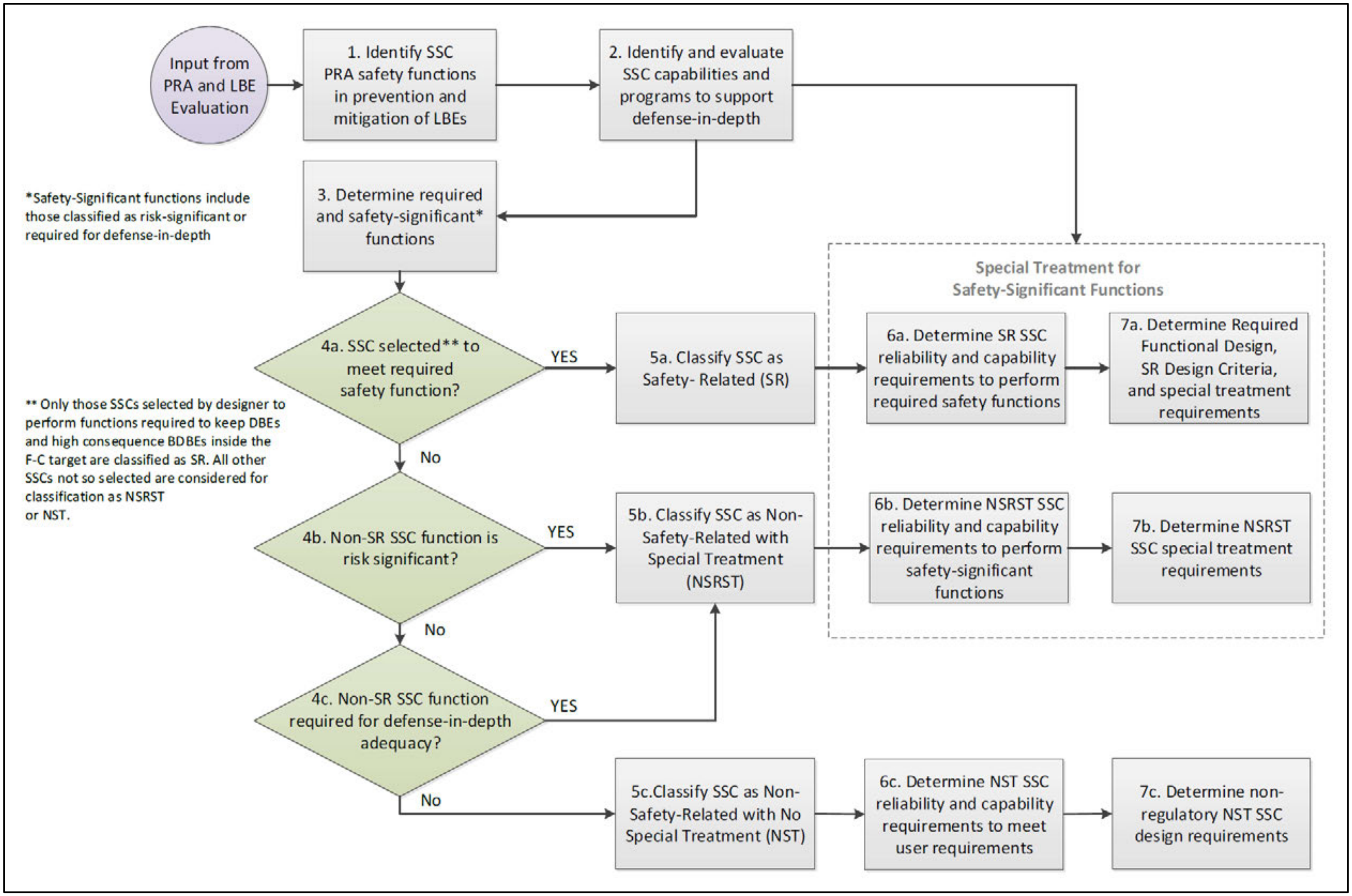

Figure 3.1-1: SSC Function Safety Classification Process

Task 1: Identify SSC PRA Safety Functions in the Prevention and Mitigation of LBEs

For this task, each LBE is reviewed, including those in AOO, DBE, and BDBE regions to determine the function of each SSC in the prevention and mitigation of each LBE. Each LBE is comprised an IE, a sequence of conditioning events, and an end state. The IEs may be associated with an internal event such as an SSC failure or human error, an internal facility hazard such as fire or flood, or an external hazard.

For those internal events caused by an equipment failure, the IE frequency is related to unreliability of the SSC, i.e., SSCs with higher reliability serve to prevent the IE. Thus, higher levels of reliability result in a lower frequency of IEs. For SSCs that successfully mitigate the consequence of the IE, their capabilities and safety margins to respond to the IE are the focus of the safety classification process and resulting special treatment. For those SSCs that fail to respond along the LBE, their reliabilities, which serve to prevent the LBE by reducing its frequency, are the focus of the reliability requirements derived from the classification treatment process. The output of this task is the identification of the SSC prevention and mitigation functions for all the LBEs.

Task 2: Identify and Evaluate SSC Capabilities and Programs to Support Defense-in-Depth

The purpose of this task is to provide a feedback loop from the evaluation of DID adequacy. This evaluation includes an examination of the facility LBEs, identification of the SSCs responsible for the prevention and mitigation of events, and a set of criteria to evaluate the adequacy of DID. A result of this evaluation is the identification of SSC functions and the associated reliabilities and capabilities deemed necessary for the DID adequacy. Such SSCs and their associated functions are regarded as safety-significant, and this information is used to inform the SSC safety classification. Additional details of the evaluation of DID adequacy are presented in Section 4.0.

Task 3: Determine the Required and Safety-Significant Functions

The purpose of this task is to define the safety functions that are necessary to meet the F-C Target for all the DBEs and the high-consequence BDBEs, i.e., the RSFs as well as other PSFs regarded as safety-significant. Safety-significant SSCs include the SSCs that perform risk-significant functions and those that perform functions that are necessary to meet DID criteria. SSCs that perform essential support to safety-significant SSCs are included as well as those directly performing risk-significant functions. The scope of the PRA includes all the facility SSCs that are responsible for preventing or mitigating the release of radioactive material. Hence, the LBEs derived from the PRA include all the relevant SSCs and mitigation functions.

There are some safety functions classified as RSFs that must be fulfilled to meet the F-C Target for the DBEs using realistic assumptions and 10 CFR 50.34 dose requirements for the DBAs using conservative assumptions. In addition to these RSFs, there are additional functions that are classified as safety-significant when certain risk significance and DID criteria are met. In most cases, there are several combinations of SSCs that can perform these RSFs. How individual SSC PSFs are classified relative to these functions is resolved in Tasks 4 and 5.

Task 4 and 5: Evaluate and Classify SSC Functions

The purpose of Task 4 and 5 is to classify the SSC functions modelled in the PRA into one of three safety categories: SR, NSRT, and NST. Tasks 4 and 5 are discussed simultaneously below as affirmative results from the evaluation performed in Tasks 4A, 4B and 4C are directly classified in the corresponding portion of Task 5.

Task 4A and 5A

In Task 4A, each of the DBEs and any high-consequence BDBEs (i.e., those with doses above 10 CFR 50.34 limits) are examined to determine which SSCs are available to perform the RSF for each. These specific SSCs are classified as SR in Task 5A and are the only ones included in analysis of the DBAs.

All remaining SSCs are processed further in Tasks 4B and 4C.

Task 4B and 5B

In this task, each non-safety-related SSC is evaluated for its risk significance. A risk-significant SSC function is one that is necessary to keep one or more LBEs within the F-C Target or is significant in relation to one of the cumulative evaluation risk metric limits. If the SSC is classified as risk-significant and is not a SR SSC, it is classified as NSRST in Task 5B.

SSC Functions that are neither SR nor risk-significant are evaluated further in Task 4C.

Task 4C and 5C

In this task, a determination is made as to whether any of the remaining non-safety-related and non-risk significant SSC functions should be classified as requiring special treatment in order to meet criteria for DID adequacy. Those that meet these criteria are classified as NSRST in Task 5B and those remaining as NST in Task 5C.

At the end of this task, all SSC functions reflected in the LBEs can be placed in one of the three SSC function safety classes: SR, NSRST, or NST.

Task 6: SSC Reliability and Capability Targets

For each of the SSC functions classified in Task 4, the purpose of this task is to define the requirements for reliabilities and capabilities for SSCs modeled in the PRA. For SSCs classified as SR or NSRST, which together represent the safety-significant SSCs, these requirements are used to develop specific design and special treatment requirements in Task 7. For those SSCs classified as NST, the reliability and capability targets are part of the non-regulatory owner design requirements.

In order to meet the risk targets (F-C Target and cumulative risk targets), SSCs that are relied upon will need to meet strict reliability performance targets and will need to demonstrate DID adequacy. Strategies to achieve design reliability targets include use of passive and inherent design features, redundancy, diversity, and defenses against common-cause failures. Programmatic actions would be used to maintain performance within the design reliability targets.

Task 7: Determine SSC Specific Design Criteria and Special Treatment Requirements

The purpose of this task is to establish the specific design requirements for SSCs which include design criteria for SR classified SSCs, regulatory design and special treatment requirements for each of the safety-significant SSCs classified as SR or NSRST, and owner design requirements for NST-classified SSCs. The specific SSC requirements are tied to the SSC functions reflected in the LBEs and are determined utilizing the same integrated decision-making process used for evaluating DID adequacy.

For SSCs classified as SR, the design criteria are referred to as Safety-Related Design Criteria (SRDC). These are derived from the Principal Design Criteria (PDC). The development of the **eVinci** micro-reactor PDC is described in EVR-LIC-GL-003, “Principal Design Criteria” (Reference 14). [

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NSRST SSCs are not directly associated with PDC but are subject to special treatment as determined by the integrated decision-making process for evaluation of DID and for meeting the reliability and capability targets set in Task 6. The safety-significant aspects of the descriptions of SSCs that should be included in safety analysis reports are defined by the (1) PDC, (2) SRDC, (3) reliability and capability targets for SR and NSRST SSCs, and (4) special treatment requirements for SR and NSRST SSCs.

4.0 Evaluation of Defense-in-Depth Adequacy

4.1 Process for Evaluation of Defense-in-Depth Adequacy

The **eVinci** micro-reactor design includes design features and administrative controls intended to provide high confidence in safe operation. These design features and administrative controls are grouped into levels of defense similar to those presented in [ ]a,c,e The objective of each level of defense is summarized in Table 4-1. The classification of the SSCs providing protection at each level of defense is also included in Table 4-1.

Table 4-1: Levels of Defense

a,c,e

The levels of defense provide a layered application of protective features such that progression to the successive level is increasingly unlikely. In general, the reactor will be protected from each initiating event by at least two independent and diverse levels of defense. Of particular focus are the measures put in place for Levels 3 and 4. The design intention of the engineered safety features supporting Level 3 is that measures are taken to ensure they can reliably provide the necessary design basis protection of the required safety functions. Diverse equipment, relative to that used in Level 3, is available to mitigate against common cause failures of the equipment such that offsite radiological consequences are minimized.

The process by which SSCs are incorporated into these levels of defense is depicted in Figure 4.1-1 (Figure 5-4 from Reference 1). Additional details related to each step follows. Many of the steps used to evaluate DID adequacy are the same as those performed to identify the LBEs. In these instances, references to the applicable task described in Section 2.1 is made rather than reiterating the information in this section.

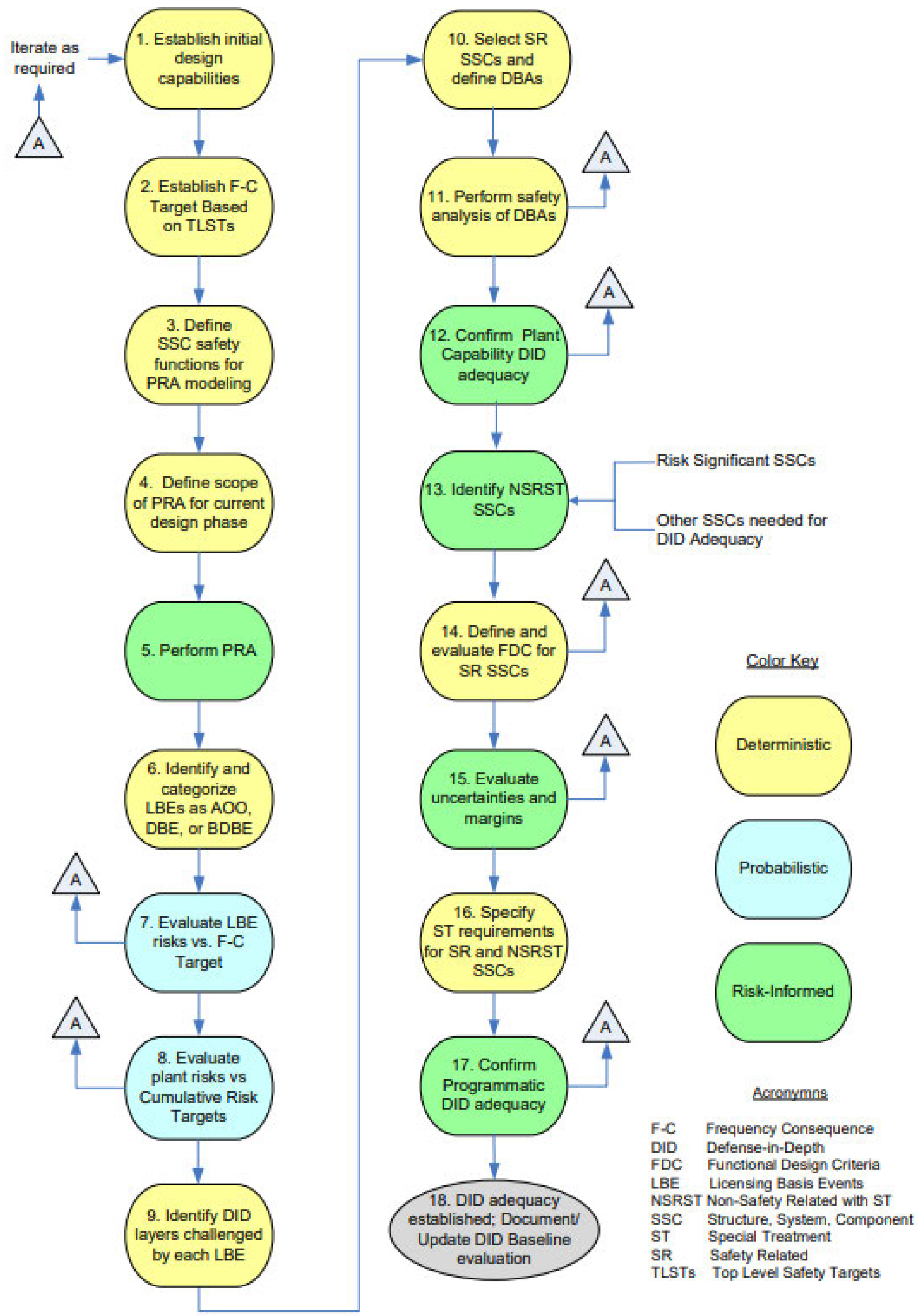

Figure 4.1-1: Integrated Process for Incorporation and Evaluation of Defense-in-Depth

Task 1: Establish Initial Design Capabilities

This task includes the identification of systems and components and their functions, including energy production functions, maintenance functions, auxiliary functions, and PRA Safety Functions and an identification of hazards associated with these SSCs. This is a purely deterministic task that produces a definition of the design in sufficient detail to begin the PRA.

Task 2: Establish F-C Target Based on Regulatory Objectives and QHOs

The F-C target is established in this task. The F-C target planned for use in the **eVinci** micro-reactor development program is described in Task 4 of Section 2.1, *Process for selection of licensing basis events*.

Task 3: Define SSC Safety Functions for PRA Modeling

The reactor-specific PRA Safety Functions are defined as part of the PRA Development/Update in Task 3 of Section 2.1, *Process for selection of licensing basis events*.

Task 4: Define Scope of PRA for Current Design Phase

In the initial stages of the design, an evaluation is made to decide which hazards, IEs, and event sequences to consider within the design basis and for designing specific measures to prevent and mitigate off-normal events and event sequences.

Task 5: Perform PRA

A PRA is performed as described in Task 3 of Section 2.1, *Process for selection of licensing basis events*.

Task 6: Identify and Categorize LBEs as AOOs, DBEs, or BDBEs

The list of AOOs, DBEs and BDBEs is compiled as described in Task 4 of Section 2.1, *Process for selection of licensing basis events*.

Task 7: Evaluate LBE Risks vs. F-C Target

The LBE risks are evaluated against the F-C target as described in Task 7a of Section 2.1, *Process for selection of licensing basis events*.

Task 8: Evaluate Facility Risks vs. Cumulative Risk Targets

The facility risks are evaluated against the cumulative risk target as described in Task 7b of Section 2.1, *Process for selection of licensing basis events*.

Task 9: Identify DID Layers Challenged by Each LBE

The layers of defense process described in Table 4-1 are used in this task to evaluate each LBE with more attention given to risk-significant LBEs to identify and evaluate the DID attributes to support the capabilities in each layer and to minimize dependencies among the layers.

Task 10: Select Safety-Related SSCs and Define DBAs

The safety-related SSCs are selected following the process described in Section 3.1, *Process for safety classification and performance criteria for SSCs*. The DBAs are defined as described in Task 6 of Section 2.1, *Process for selection of licensing basis events*.

Task 11: Perform Safety Analysis of DBAs

This task relates to traditional deterministic safety analysis. Additional details related to deterministic safety analysis are described in EVR-SAR-GL-001 (Reference 12).

Task 12: Confirm Facility Capability DID Adequacy

The information gathered in the previous steps is used as one source of input to an IDP to draw a conclusion that each layer of defense is sufficient. As part of the DID adequacy evaluation, each LBE is evaluated to confirm that risk targets are met without exclusive reliance on a single element of design, a single program, or a single DID attribute.

Task 13: Identify Non-Safety-Related with Special Treatment SSCs

This task relates classifying SSCs as NSRST. The SSCs are classified as described in Tasks 4 & 5 of Section 3.1, *Process for Safety Classification and Performance Criteria for SSCs*.

Task 14: Define and Evaluate Required Functional Design Criteria for SR SSCs

This task defines and evaluates required functional design criteria. PDC provide a bridge between the DBAs and the formulation of SRDC for the SR SSCs. DID attributes such as redundancy, diversity, and independence, and the use of passive and inherent means of fulfilling RSFs are used in the formulation of PDC.

Task 15: Evaluate Uncertainties and Margins

This task relates to evaluating the uncertainties and margins associated with the results. The uncertainties and margins are evaluated as part of the evaluation of the LBEs against the F-C target discussed in Task 7a of Section 2.1, *Process for selection of licensing basis events*.

Task 16: Specify Special Treatment Requirements for SR and NSRST SSCs

The requirements for SR and NSRST SSCs are defined to ensure the performance of the PSFs with significant margins and with appropriate degrees of reliability. These include numerical targets for SSC reliability and availability, design margins for performance of the PSFs, and monitoring of performance against these targets with appropriate corrective actions when targets are not fully realized. Another consideration in the setting of SSC performance requirements is the need to assure that the results of the facility capability DID evaluation in Task 12 are achieved, not just in the design, but in the as-built and as operated and maintained facility throughout the life of the facility. The SSC performance targets are set during the design IDP that is responsible for establishing the adequacy of DID. In addition to these performance targets, further special treatments may be identified.

Task 17: Confirm Programmatic DID Adequacy

The adequacy of the programmatic measures for DID is driven by the selection of performance requirements for the safety-significant SSCs in Task 16. The programmatic measures are evaluated relative to the risk significance of the SSCs, the roles of SSCs in different layers of defense, and the effectiveness of special treatments in providing additional confidence that the risk-significant SSCs will perform as intended.

Task 18: DID Adequacy Established; Document/Update DID Baseline Evaluation

The RIPB evaluation of DID adequacy continues until the recurring evaluation of facility and programmatic DID associated with design and PRA update cycles no longer identifies risk-significant vulnerabilities where potential compensatory actions can make a practical, significant improvement to the LBE risk profiles or risk significant reductions in the level of uncertainty in characterizing the LBE frequencies and consequences. At this point, a DID baseline can be finalized to support the final design and operations of the facility. The successful outcomes of Tasks 12 and 17 establish DID adequacy.

Appendix A: Initial SSC Classifications

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